University of Malaya

Simulation of Implant Fitting in The Hip Bone Using Maya

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DECLARATION

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

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September 2003

DISCLAIMER

ABSTRACT

In today's medical world, attention of researchers of orthopedic surgery now turned toward using 3-D visualization and virtual environment technologies to help surgeons plan for patient specific and complex procedures of operation. For a successful hip surgery, planning is required to decide on type and size of the implant and the reconstruction of the joint geometry. Biomedical analysis and determination of the center of rotation enable the surgeon to choose the theoretically optimal position of the implant.

We can plan for the operation by using a computer simulation. Computer simulation provides the conceptual basis to aid the analysis of complex phenomena without building the actual system. From this simulation, surgeon can analyze, create a surgical plan to insert the proposal implant into patient's hip.

This proposal project paper will described about the system that will be develop and will explain about all the requirement in developing the project of Simulation of implant fitting in the hip bone. It contains four main chapter; introduction, literature review, methodology, system analysis and system design.

Methodology of system development that will be used is the waterfall model. One of the requirements that will be used to develop this project is Maya 4.5 Learning edition. The designing of this system is only a first planning and maybe will change depends on the current situation.

ACKNOWLEDGEMENT

To finish an academic exercise, the effort that the people supporting is no doubt an enormous task. Firstly I would like to express my utmost gratitude to my supervisor, Ms. Mangalam Sankupellay for her guidance, advice and encouragement. I salute her with a round of applause.

Special thank to Dr. Selvanathan Narainasamy, the project moderator for his valuable suggestion and comments. And a big thanks Dr. Soraya for her patient in explaining the important things about hip surgery and the benefit of my project in the world of orthopedic surgery.

Thanks to all my fellow course-mates for sharing their knowledge with me throughout the whole project. And also to all my fellow seniors who had done a great jobs in advising me on what to do during the system development stage. Last but not least, I would like to thanks my family for their continued encouragement and support.

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1.0 Introduction

This introductory chapter gives a brief description or purpose of the project and problems to be solved. The significance and rationale of the project will be discussed here. Furthermore, the system scope and its limitations will also be covered later in this chapter.

1.1 Problem Statement

Imaging technology has advanced by leaps and bounds. In the past years computer-assisted methods have become more and more accepted in the field of orthopedic-surgical treatment. 2-D images like ultrasound, Computer Tomography (CT) and Magnetic Resonance (MR) imagery provide data that helps surgeon simulate procedures on-screen and plan for optimal surgical intervention. The current standard for planning hip surgery relies on X-ray images which cannot render the knobs and niches of bone with the precision that some hip surgery demands. This force the doctor to make last minute decision during the operation. Another reason that the surgical plan is more difficult with the 2-D pictures is because of a poor quality of the image and it also not very accurate because the surgeon cannot imagine the actual representation of the bone and also the implant.

The new methods of 3-D image visualization seem to solve the problems of conventional X-ray technology. Today's navigation systems allow the surgeon to control visually a number of operation steps at a virtual bone model. Beside, aspects of implant fixation such as fitting accuracy and size of bone contact surface also can be determined. Due to the complexity, computer-assisted analysis of 3-D model is important to decision making.

In this paper, I will describe about a system that can assist the surgeon during technically demanding phase as the procedure in the surgery. To make sure that the operation is success, we have to retrace the steps made during computer simulation.

1.2 Project Definition

This paper will described about the capability for more accurate implant placement to its final position of the patient's anatomy. By using 3-D models of hip implant that have been designed from the 2-D models and also a femur bone, we do a simulation to actually figure out where the implant should move, what is going to fit and how to make the implant fit.

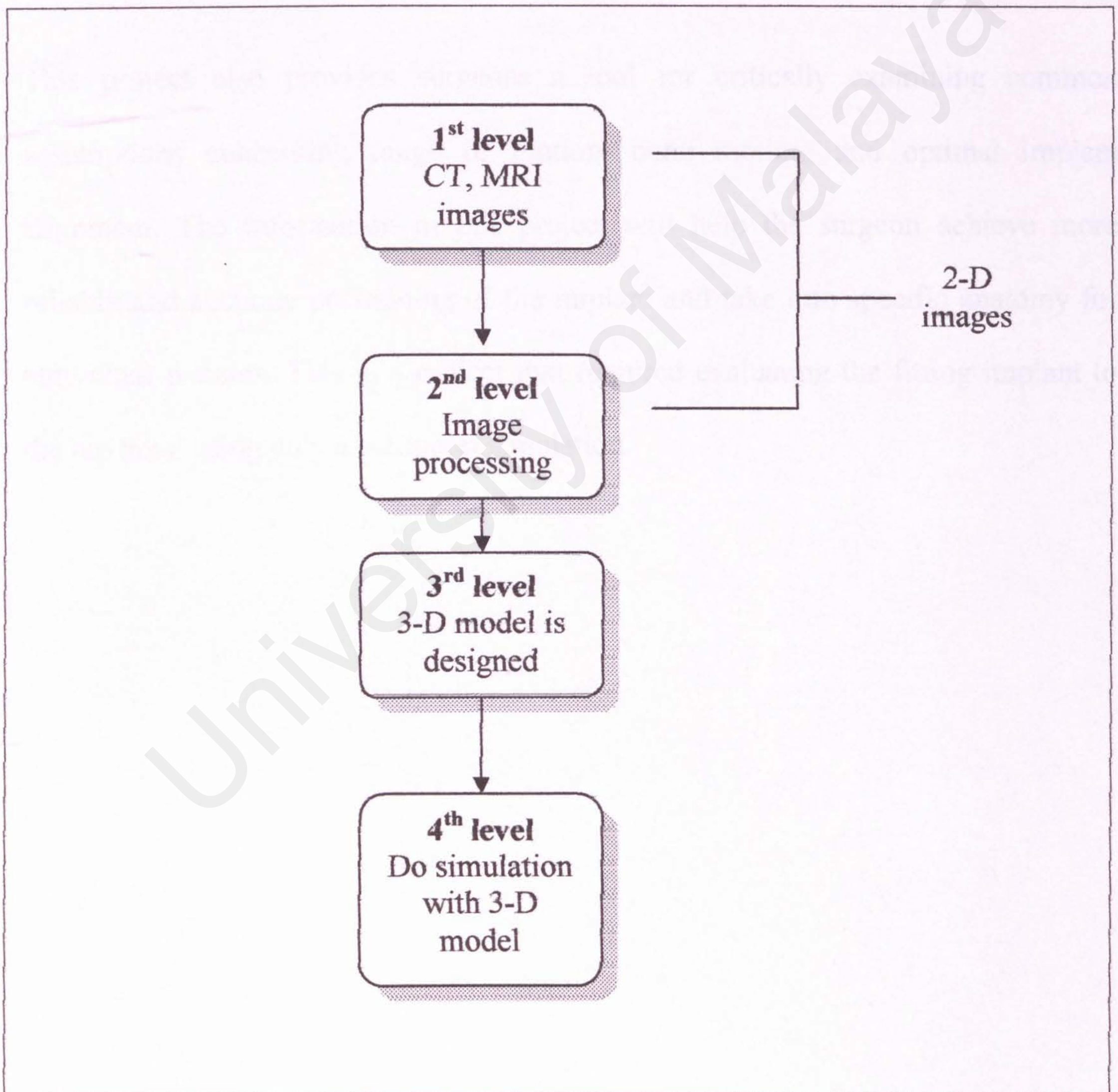


Figure 1 .1: Flow chart of project level

In this project, I will focus on the 4th level, which is do a simulation by the 3-D models that has been given to get the accurate measures for the implant to fit with the hip bone before the real operation can be made. With these models, we can try out different approaches and thereby determine the best operating strategy. What makes 3-D such a useful tools is the way it simulates real objects. From this simulation, surgeon can analyze, create a surgical plan to insert the proposal implant into patient's hip. This way, the errors during the surgery are minimized.

This project also provides surgeons a tool for critically examining common assumptions concerning range of motion, bone motion, and optimal implant alignment. The information in this project will help the surgeon achieve more reliable and accurate positioning of the implant and take into specific anatomy for individual patients. This is a project that required evaluating the fitting implant to the hip bone using only a computer simulation.

1.3 Project Objective

There are some reasons or objectives which this system has been proposed:

i. **To produce a system with high accuracy**

System is able to accurately simulate real-time procedure, reliable to actually implement in an actual surgery, identify the techniques which will produce the most suitable of fitting the hip implant to make the operation is the safest and most effective in medical procedures. This is important to avoid traumas and complications in fitting the implant into the hip bone.

ii. **To produce a system with good quality**

System must be able to demonstrate a consistent and high quality output when running the simulation. As the specimens for this thesis are limited, a perfect output would enable further elaborations towards various variables and able to be used on any type of bone size or implant-type.

iii. **To reduce financial and time cost**

With the aide of computer simulation, the actual procedure would take a minimized required time, hence lessens financial burden.

iv. **To provide better scenario-based of practice**

Offers user-friendly of simulation to train medical student and to help surgeon advanced with the individual patient's anatomy before surgery therefore can improve the skills and the effectively of orthopedic surgery.

1.4 Project Scope

Before starting the development of the system, the boundary of the system must be clarified. The boundaries of this system are:

i. The simulation will only involve a specific adult human femur bone and one hip implant consist of a femoral head and stem that replaces the ball of the hip joint and upper part of the thigh or femur bone.

ii. The simulation process will only use the tools included in the Maya 4.5 Unlimited and also Maya scripting, Maya Embedded Language (MEL).

iii. This system will only concentrate on the femur bone and also the implant.

This project is a stand alone system, which generally is used by two types of user. Two types of users are:

i. Surgeons from the orthopedic surgery

- The responsibility is to do simulation from the 3-D model of femur bone and implant that has been given.

ii. Medical students

- This system is used by the students to study the representation of human femur bone and implant in a 3-D visualization.

1.5 Project Limitations

For every project, there are always some limitations to the program that has been developed. By identifying the limitations or constraints in the program, there would be much easier for future enhancement. They would be:

i. **Area of the Simulation**

It only covers the development of 3-D model simulation of the implant to fit in the hip joint. Simulation of implant is being done only around the area of the femur bone.

ii. **Types of material**

The project also covers the specific material that has been used in I implant like ceramic, cobalt chrome, metal and polyethylene plastic.

iii. **Limited target user**

The system only will be using by individual that have a knowledge in orthopedic medical site like surgeons and medical students.

1.6 Project Activities

Several forms of activities were made to ensure the smoothness of project development. The following show the table of activities that has been done:

Table 1.1: Project activities

Activities	Description
Planning	• problem statement • objective and definition • scope and limitation
Literature and Existing System Review	• thesis and paperwork review • existing system review • survey information about hip, simulation and implant
Methodology	• selecting the best model that suitable • determined functional and non-functional requirements
System Analysis and System Design	• flow chart of system • data flow diagram • user interface design
Implementation	• doing the scripting and start scaling the implant
Testing	• make a suitable changes to the implant size so that it can fit to the femur bone
Documentations	• provide report for the project and documentations for the user

1.7 Project Schedule

ID	Task Name	Duration	Start	Finish
1	Project definition	18 days	Mon 6/2/03	Wed 6/25/03
2	Literature review	20 days	Thu 6/26/03	Wed 7/23/03
3	Methodology	10 days	Thu 7/24/03	Wed 8/6/03
4	System Analysis	24 days	Thu 8/7/03	Tue 9/9/03
5	System Design	20 days	Wed 9/10/03	Tue 10/7/03
6	Implementation	90 days	Wed 10/8/03	Tue 2/10/04
7	System Testing	28 days	Wed 2/11/04	Fri 3/19/04
8	Documentation	200 days	Mon 6/16/03	Fri 3/19/04

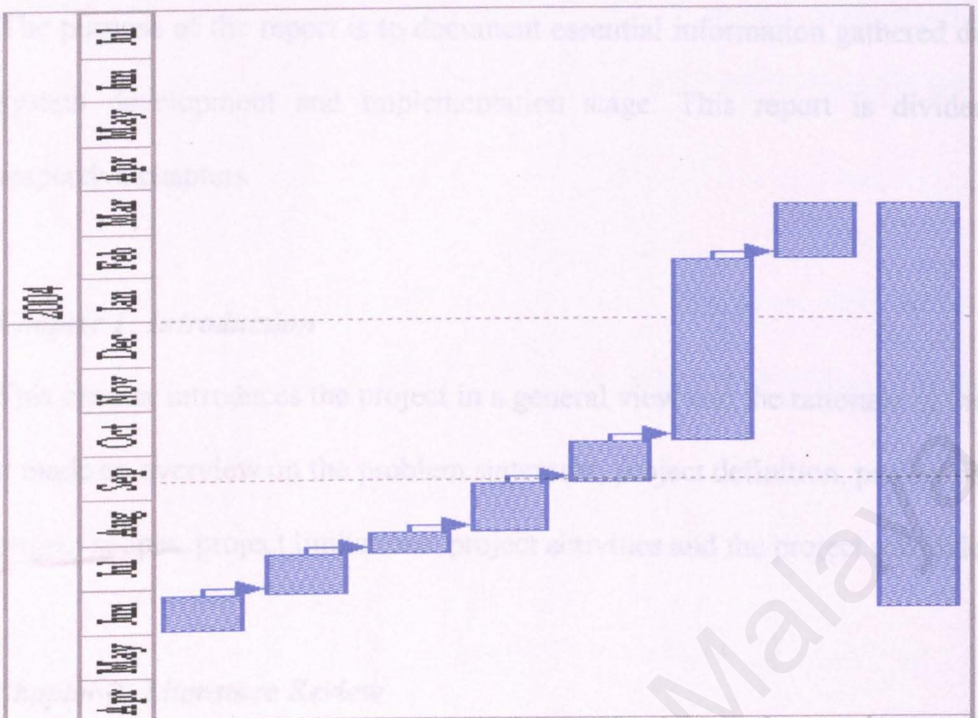


Figure 1.2: Project Schedule of Simulation of implant fitting hip bone using Maya

1.8 Report Layout

The purpose of the report is to document essential information gathered during this system development and implementation stage. This report is divided into 7 respective chapters.

Chapter 1: Introduction

This chapter introduces the project in a general view and the rationale of the project. It made an overview on the problem statement, project definition, project objectives, project scopes, project limitations, project activities and the project schedule.

Chapter 2: Literature Review

This chapter gives brief explanation on topics researched and studies that are relevant to this project. It is the combination between literature search and literature review. This includes techniques and ideas used in the building of the system.

Chapter 3: Methodology

This chapter emphasizes on the justifications for the chosen project methodology. It also determine the system requirement such functional and non-functional requirement. It also explains how the requirements for this project were acquired.

Chapter 4: System Analysis and System Design

This chapter describes the design considerations including processing design, the user interface design, context diagram and the simulation techniques of this project.

Chapter 5: System Implementation

This chapter describes the implementation of all the system's module. This includes all the modules describe and also the function module that navigate the system.

Chapter 6: System Testing

This chapter includes the testing of the scripting in the system. Concepts introduced include function testing, performance testing, acceptance testing and installation testing.

Chapter 7: System Evaluation

This chapter discusses the need for empirical evaluation and gives several examples to show how measurements can be used to establish a baseline for quality and productivity.

1.9 Summary

This chapter focuses mainly on the introduction of this project. A brief introduction and definition are stated in the first part of this chapter, which is the Project Overview. Apart from that, relevant information and topics are also being discussed consequentially. Topics included are Project Definition, Project Objectives, Project Scope, Project Limitations, Project Activities, Project Schedule and Report Layout. The research and development of this proposed system will take about 8 months.

2.0 Literature Review

Most of my researches were done during this period of time. This subsection contains all the research has been done on the existing current system including reviews on the features, capabilities, and so on. The weaknesses on existing current system were identified in order for this project to overcome and the strengths of existing simulation from 3-D model were studied so that it can be adapted into this project.

2.1 About Simulation

In the Oxford Advanced Learner's Dictionary of Current English (5^{th} Edition), word **Simulation** is defined as:

"The deliberate making of certain conditions that could exist in reality, in order to study them or learn from them"

Computer simulation is a computerization of the developed model, which is run over to study the implications of the defined interactions of the parts of the system. It embodies the principle of "learning by doing"; to learn about the system we must first build a model of some sort and then operate the model. The main objective of computer simulation is to provide the conceptual basis to aid the analysis of complex phenomena without building the actual system. This technique have been increasingly used since the late fifties to either solve or to gain better understanding of the problems encountered in a wide range of disciplines.

We need to do simulation because: (1) the model is very complex with many variables and interacting components; (2) the underlying variables relationships are nonlinear; (3) the model contains random varieties; and (4) the model output is to be visual as in a 3-D computer animation. Simulation is tightly coupled and iterative three component process/phases composed of: (1) model design; (2) model execution; (3) execution analysis.

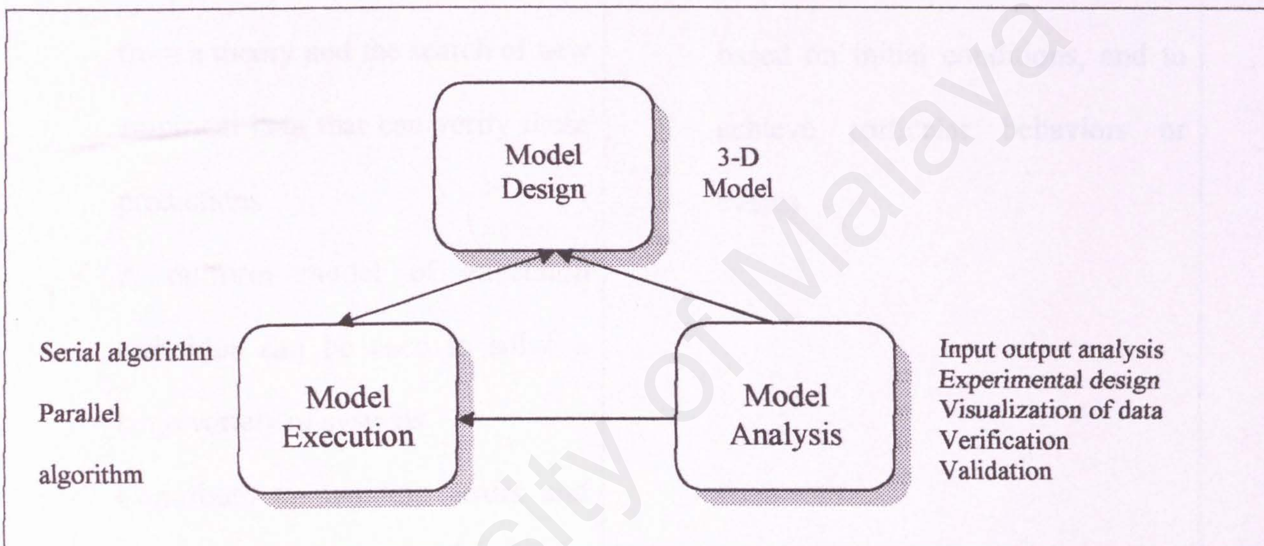


Figure 2.1: Three subfields of Computer Simulation

2.1.1 Advantages and Limitations of Computer Simulation

Table 2.1: Comparison between the advantages and limitations Of computer simulation

Advantages	*Limitations*
✓ Permits the discovery of new predictions that can/must be derived from a theory and the search of new empirical data that can verify these predictions ✓ A uniform model of execution technique can be used to solve a large variety of systems ✓ Contribute to avoiding errors and waste of resources ✓ Attempts of construction of a scene can be simulated with the computer and viewed from points that may be practically impossible to view in reality	• Difficult external validation • It is difficult to predict outcome based on initial conditions, and to achieve particular behaviors or events

2.2 Femur Bone Anatomy

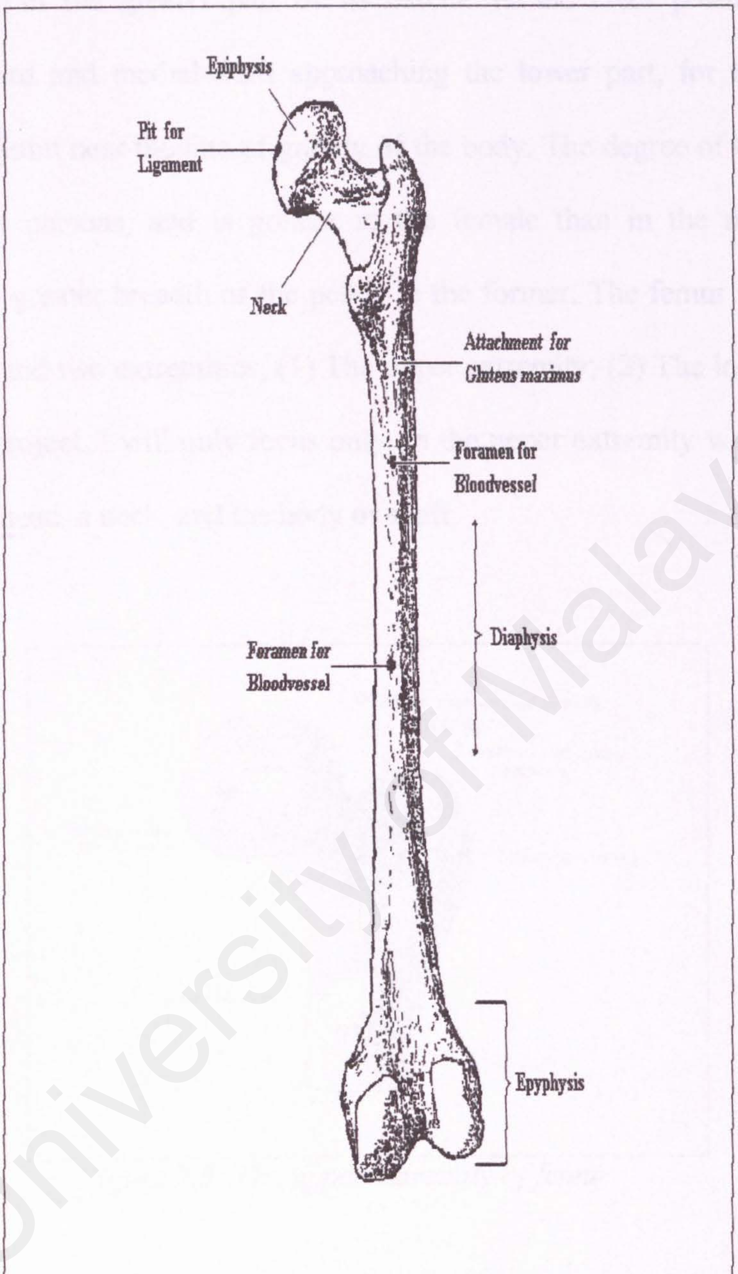


Figure 2.2: Structure of the femur

The human femur bone is the longest and strongest in the skeleton with a shape that is almost cylindrical in the greater part of its extent. In the erect posture, it inclines gradually downward and medial-ward approaching the lower part, for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies in different persons, and is greater in the female than in the male, which is contributed by the greater breadth of the pelvis in the former. The femur is divided into three part, a body and two extremities; (1) The upper extremity; (2) The lower extremity. However, in this project, I will only focus only on the upper extremity which represents for examination a head, a neck, and the body or shaft.

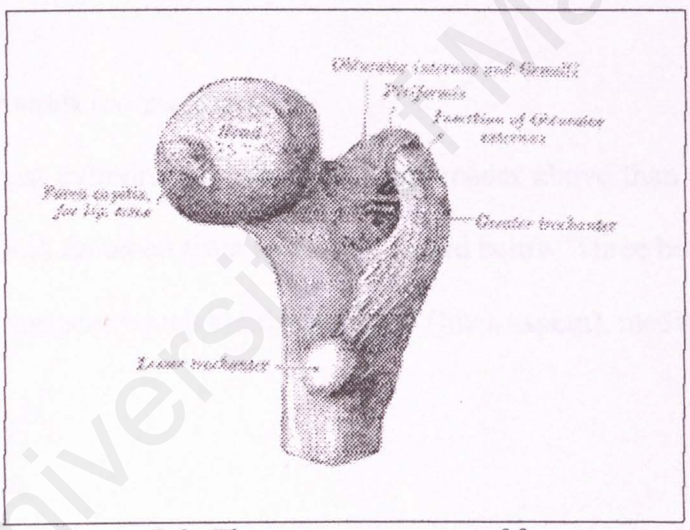


Figure 2.3: The upper extremity of femur

1. The head (*caput femoris*)

Shape is globular, directed upward, medialward, and a little forward, the greater part of its convexity being above and in front. Surface is smooth, coated with cartilage in the fresh state which gives attachment to the ligamentum teres.

2. The neck (*collum femoris*)

Connect the head with the body, and forming a wide angle opening medialward with the latter. In an adult, the neck forms an angle of about 125° with the body, but this may vary in inverse proportion to the development of the pelvis and stature. The neck has two surfaces, anterior and posterior, and two borders, superior and inferior.

3. The body or shaft (*corpus femoris*)

The body is almost cylindrical in form, a little broader above than in the centre, as well as broadest and flattened from before backward below. Three borders are present to separate three surfaces which are the posterior (linea aspera), medial and lateral.

2.3 The Hip

Hip is the joint which connects the leg upper part of the body. This hip joint consists of two parts: a socket and a ball. A portion of the pelvic bone forms the cup, or "socket" called the acetabulum. The "ball" or femoral head at the top of the thigh bone fits into it. A smooth, glossy substance, called cartilage, covers the two bone surfaces where they meet, providing a cushion for ease of motion. This joint is moving every time you take a step. It flexes, extends and moves out the side.

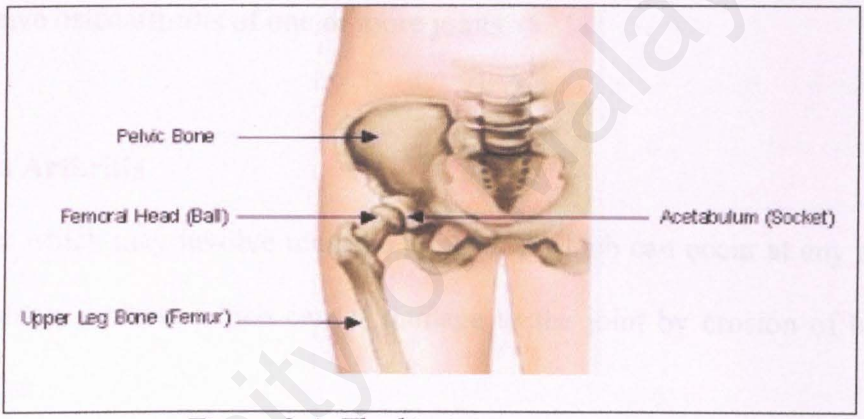


Figure 2.4: The hip joint

2.3.1 Common Hip Disorders

In many hip disorders the cartilage is destroyed and the smooth contact between the head of the thigh bone and the socket becomes disrupted. This may lead to pain, stiffness, limp, and shortening of the leg. Types of hip disorders:

1. Osteoarthritis

It is characterized by destruction of the cartilage and a bony overgrowth. It is a degenerative process, a "wear and tear" type of arthritis. As people age it is not uncommon to have osteoarthritis of one or more joints.

2. Rheumatoid Arthritis

Chronic disorder which may involve multiple joints and which can occur at any age. This is inflammatory process which causes damage to the joint by erosion of both cartilage and bone.

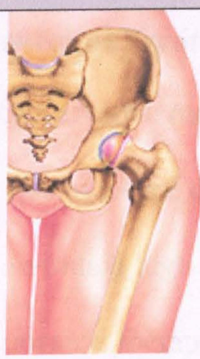
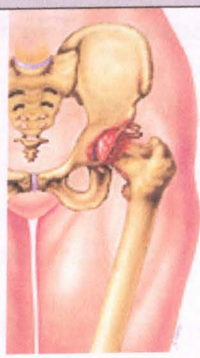
3. Avascular Necrosis

Results from a disruption of blood flow to the head of the femur causing local bone death which may eventually lead to joint destruction. There are several conditions that may be linked to the occurrence of a vascular necrosis, such as; steroid use, previous trauma to the hip and certain blood disorders.

4. Developmental disorders

This may cause abnormal joint anatomy which could lead to arthritis.

Table 2.2: The difference between healthy, problem hip and hip prosthesis

Healthy Hip	**Descriptions**
	In a healthy hip, the smooth ball on the end of the thigh bone fits easily in the end of the hip socket to form the "ball and socket" joint. A layer of cartilage covers the ends of these bones, serving as a cushion while allowing the ball to glide easily within the socket.
Problem Hip	**Descriptions**
	Severe pain and decreased movement can result as the cushion of cartilage wears away in a hip joint affected by osteoarthritis or other diseases. The joint surfaces are allowed to rub against each other, becoming rough, pitted and irritated.
Hip Prosthesis	**Descriptions**
	The hip prosthesis consists of a specially designed ball and socket that replaces your worn hip joint. The ball and stem replace the warn ball of the thigh bone. A cup replaces the rough hip socket. The prosthesis has smooth surfaces that fit together and allow the ball to move easily and painlessly within the socket, much like a healthy hip.

2.3.2 Treatment Options

There are two treatment options that can be made through these all situations:

i. Non-surgical Treatment

Various conservative measures are used to decrease pain. These may include:

- Use of a cane or walker
- Avoiding high impact activities
- physical therapy

ii. Surgical Treatment

If these measures fail to reduce the symptoms, your surgeon may recommend surgical replacement of the hip joint. Indications for surgery:

- severe hip pain
- failure to respond to conservative treatment
- abnormal x-rays

2.4 What is Hip implant?

The artificial joint or hip implant components consist of a shell (acetabular cup) and a liner that replaces the socket of the hip joint, and a femoral head and stem that replaces the ball of the hip joint and upper part of the thigh or femur bone. The materials used in the implant are specially developed and sterilized for medical use. The implant integrates with the natural bone structure and functions just like a normal hip. The implant is designed to replicate the human anatomy, the relatively simple ball-and-socket structure of the hip joint.

2.4.1 Types of Hip implant

In some implant, the stem and ball are one piece. On others, they may be two separate pieces. If the separate piece, it is usually secured to the top of the stem after the stem has been inserted.

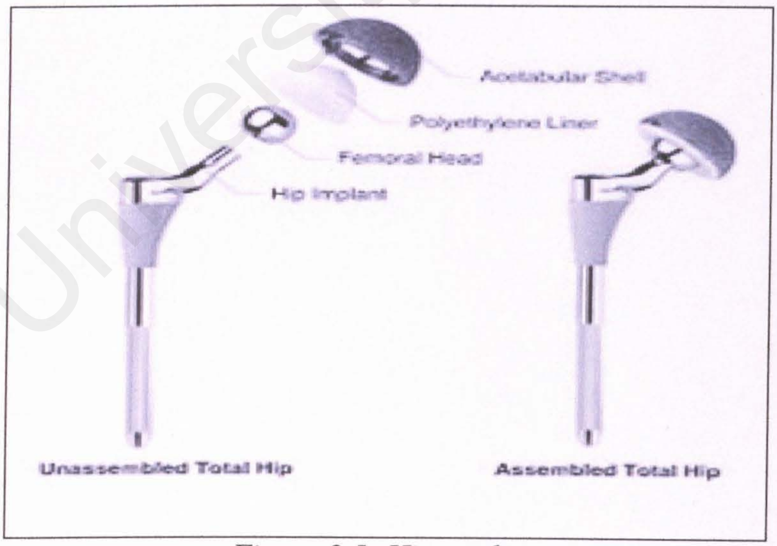


Figure 2.5: Hip implant

One type of hip implant that replaces the socket consist a metal shell that is lined with a plastic linear. Another one has the metal shell and plastic liner as one component. The head of implant is a crucial component, replacing the top of the natural thighbone. Heads are typically made of cobalt chrome or ceramic and are produced in varying diameters and neck lengths to fit the patient's anatomy. This project will focus on the socket consist a metal shell that is lined with a plastic linear and a femoral head implant.

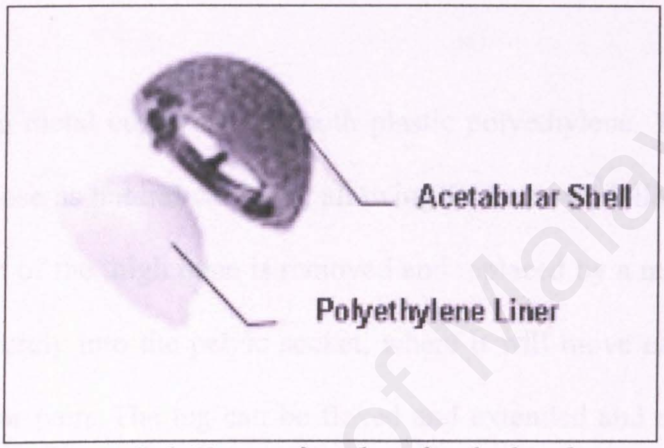


Figure 2.6: Types of implant for the head

2.5 About Hip Replacement

In Hip replacement surgery or Total Hip Replacement, the ball and socket that have been damaged by arthritis are removed and replaced with artificial parts made of metal and a durable plastic material. Hip replacement is comprised of two basic components: the femoral component and the acetabular component. Each of these can in turn be comprised of one or more pieces.

The surgeon inserts a metal cup with a smooth plastic polyethylene. The plastic lining serves the same purpose as natural cartilage, allowing for smooth, following movement. The diseased ball part of the thigh bone is removed and replaced by a metal ball. Finally, the ball is placed securely into the pelvic socket, where it will move easily and without causing any friction or pain. The leg can be flexed and extended and moved out to the side, as with your real hip.

Figure 2.7: Hip replacement

2.5.1 Cemented and Cementless Hip Replacement

Artificial implants of the joint can either be cemented or non-cemented. Cemented implants are usually reserved for older patients with poor quality bones that lack strength to help support their body weight. Non-cemented implants are for young, healthy individuals with strong and healthy bones. The basic differences between: cemented hips use cement to secure an implant to the bone; while cementless, the bone heals directly to the prosthesis. Today, most socket are implanted with cementless technique either using a press-fit where the socket of the bone is reamed to a millimeter less than the diameter of the metal shell or using supplemental fixation, such as screws, on the cup to help attach the bone.

2.6 Three Dimensional Environments

3-D environment allowing the surgeon to position their implant design in a reference anatomy represent by the CT data set before the operation. Once the bone-implant position is defined an automatic procedure, the surgeon would automatically "fit" the implant design into a database of human bones CT data sets. For each bone in the database, the procedure will calculate a set of indicators summarized in a synthetic report that will be used by the surgeon to evaluate the model on statistical basis. Table below describes the differences between 2-D and 3-D operation environment.

2.6.1 Relation 3D Modeling to Medical Operation Planning

Images acquired from CT scans or MRI is usually used as a foundation for constructing a 3D model in assisting a medical surgery procedure. Each image is then pre-processed to reduce noise, followed by the process of segmentation and finally, surface reconstruction to convert the 2D image slices into a 3D surface model. Even before the technology of virtual simulation emerged, these 3D models themselves have been found to be tremendously helpful prior to carrying out a medical surgery. The advantages of 3D modeling (especially in surgery planning) can be described as follows:

1. Multiple views, detail views, and cut away views can be easily generated from the model
2. 3D modeling allows experimentation with perspective, flare, viewing angle, and lighting to achieve the maximum visual impression
3. 3D reconstruction allows the visualization and deciphering of complex anatomical organizations that cannot be perceived on 2D images
4. It offers new possibilities for diagnostics and preoperative planning, hence encouraging the manufacturing of individual implants
5. The newer technologies in 3D image visualization seem to solve the problems of the conventional X-ray technology caused by inexactly-defined magnification factor and bone morphology

Table 2.3: The comparison between 2D and 3D environments

2-Dimensional	3-Dimensional
Advantages: • simple routine diagnostics • simple data analysis • simple comparison/quality control on the postoperative radiograph • more favorable cost-benefit relation	*Advantages:* • precise description of anatomical structures • precise determination of implant size • analysis of joint movement is possible • coupling to navigation or operation robot
Disadvantages: • missing spatial description of the anatomical structures • determination of implant size only with standard X-ray technology • to date no coupling to navigation or operation robot	*Disadvantages:* • more complicated diagnostics (primary taking radiographs, secondary CT/MRT) • more complicated CT data analysis • no routine comparison of 3D planning and operation result

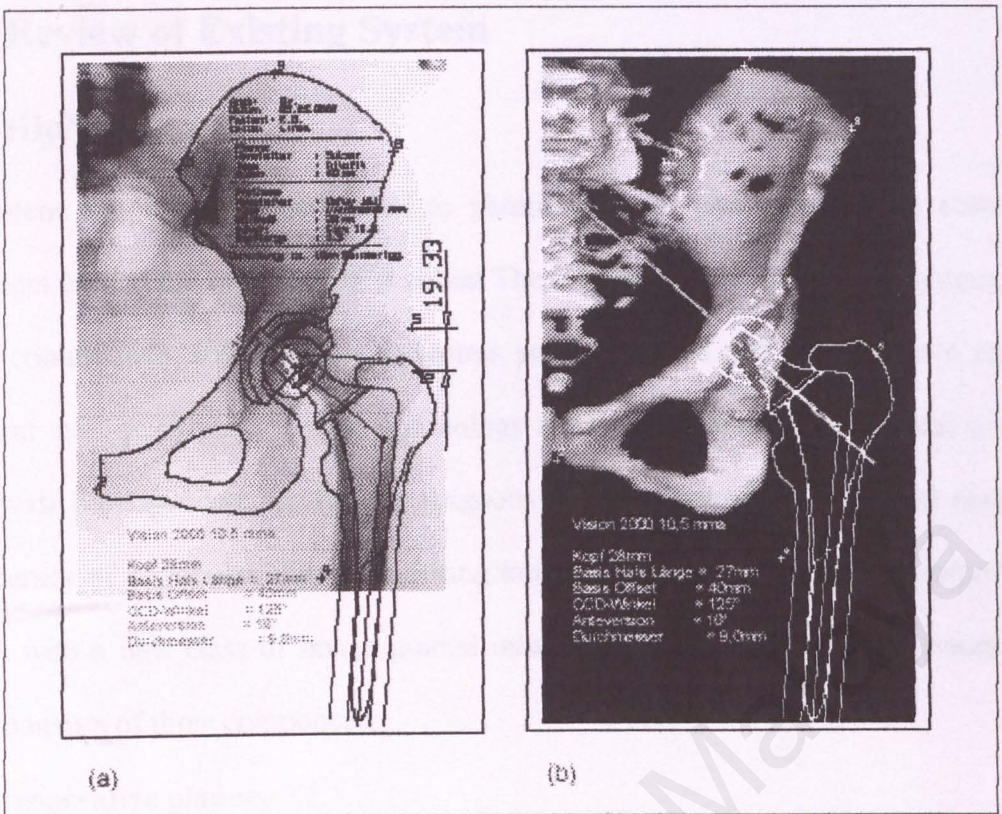


Figure 2.8: Comparison of 2D planning (a), with 3D planning (b) with optimal joint reconstruction

2.7 Review of Existing System

2.7.1 HipNav system

The system that has been developed to permit accurate placement of the acetabular component in total hip replacement is called The Hip Navigation or HipNav system. This system continuously and precisely measures pelvic location and track relative implant alignment intraoperatively. HipNav technology is used to gauge current clinical practice and provide intraoperative feedback to surgeons with the goal of improving the precision and accuracy of acetabular alignment during total hip replacement. This system provides surgeon with a new class of image guided measurement tools and assists devices. The system consists of three components:

i. **Preoperative planner**

   Allows the surgeon to specify the alignment of the acetabular component within the pelvis, based upon preoperative computed tomography (CT) images.

ii. **ROM simulator**

   A kinematics Range of Motion (ROM) simulator determines range of joint motion based upon the specific bone and implant geometry and alignment. The feedback provided by the simulator permits the surgeon to determine the optimal, patient-specific acetabular implant alignment for any implant system and determines an "envelope" of safe of motion.

iii. Intraoperative tracking and guidance system

Several devices are used during surgery to allow the surgeon to accurately achieve the implant specified in the preoperative plan. An interoperative computer displays to the surgeon the position and orientation of the implant with respect to the patient at the time of implant placement. A cadaver trial has been undertaken to evaluate the accuracy of the HipNav System and to test the ability to use the surface geometry of bone to register the preoperative plan with the intraoperative position of the pelvis. Figure 2.9 shows the HipNav cadaver trial at Shadyside Hospital, July 24, 1996.

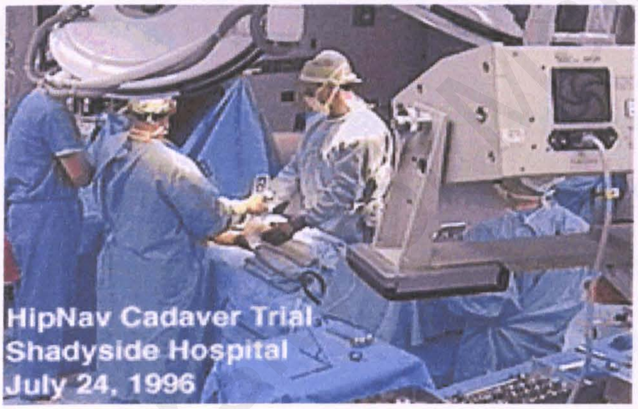


Figure 2.9: HipNav cadaver trial

Benefits of the HipNav System:

- ✓ Reduce dislocations following total hip replacement due to acetabular malposition
- ✓ Determine and potentially increase the "safe" range of motion
- ✓ Reduce wear debris resulting from impingement of the implant's femoral neck with the acetabular rim
- ✓ Track in real time the position of the pelvis and acetabulum during surgery

HipNav represents a new class of technologically advanced measurement and sensors, blending the fields of computer science, robotics and engineering with surgery to solve the real clinical problems. This may be the first surgical navigation tool ever used clinically that can intraoperatively and accurately measure pelvic position and motion, as well as acetabular alignment during surgery. With its basis in image guided technologies, the system represents a new generation of preoperative and intraoperative tools available for surgeons and researchers to measure current practice, with the potential to impact the way surgery is planned, simulated, and executed.

2.7.2 Image Guided Surgery

Dr.C.J.Thakkar, the first and only surgeon from India, trained in computer guided surgery at Pittsburgh (USA) and various centers in Germany, is happy to announce the establishment of the first computer assisted joint replacement center in the country. Computer Guided Surgery is also known as Image Guided Surgery Or Surgical Navigation.

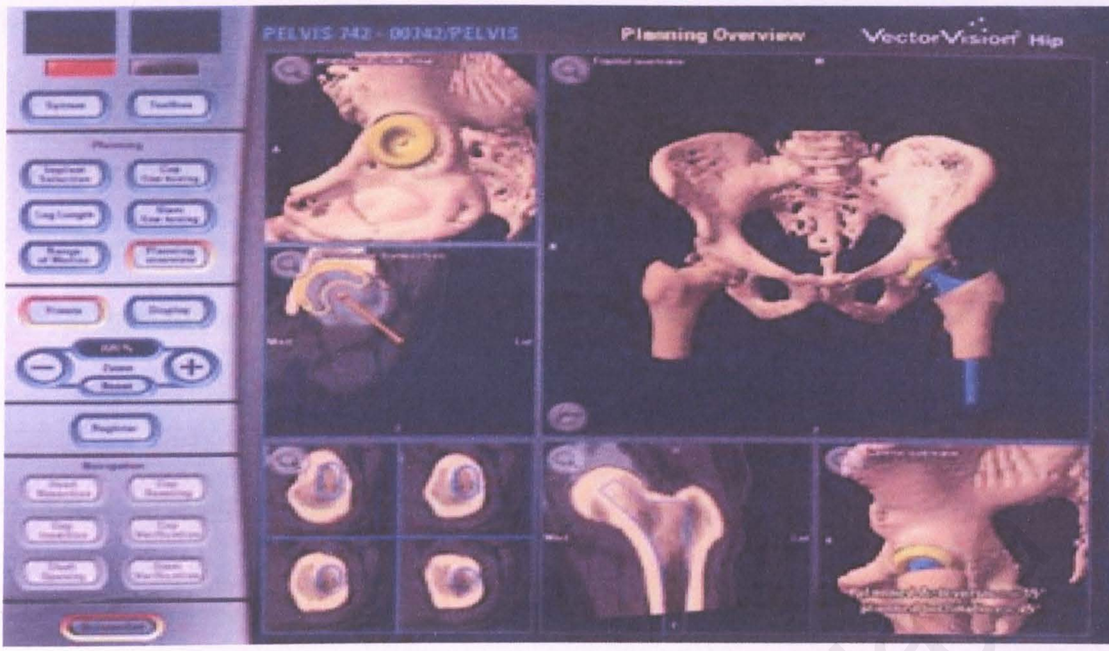


Figure 2.10: Picture of hip screen

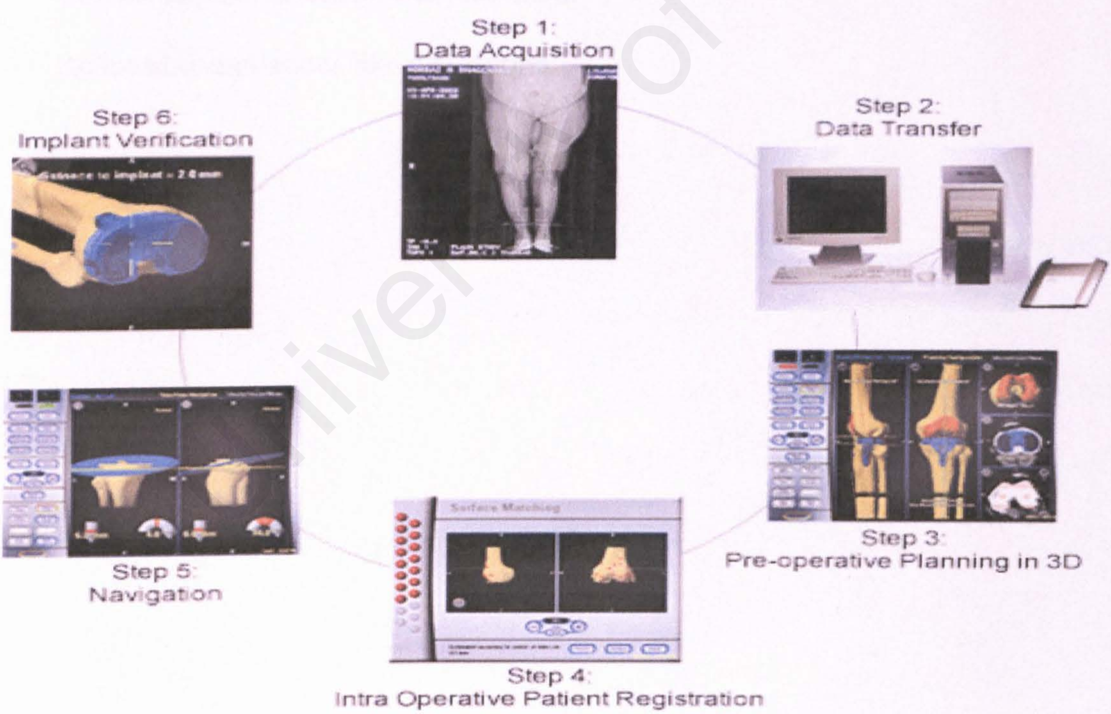


Figure 2.11: Intra operative patient registration

The system helps in:

- ✓ Range of motion analysis before surgery
- ✓ Restoration of soft tissue balance
- ✓ Restoration of limb length
- ✓ Minimally invasive technique

Advantages of Computer guided surgery:

- ✓ 3 Dimensional planning
- ✓ Constant guidance, monitoring and conformation for surgery
- ✓ Range of motion analysis to achieve maximum function
- ✓ Correct implant selection and placement
- ✓ Reduced compilations like dislocation

Table 2.3: The comparison between conventional and computer assisted surgery

Computer Assisted Surgery	Conventional surgery
✓ 3 Dimensional planning ✓ Direct measurement = accurate sizing ✓ Implant placement precise ✓ Minimal chance of hip dislocation ✓ Pre op simulated range of motion analysis	✓ 2 Dimensional planning ✓ X-ray magnification affects implant selection ✓ Implant placement by intuition ✓ Chances of hip dislocation ✓ Range of motion analysis not possible

2.8 Case Study: Acetabular Hip Implant Analysis

The cup, which is a shell/liner dome, is implanted into bone, once the bone has been hollowed out using a grater. The smooth cup assembly analysis was conducted in both two dimensions as well as in three dimensions. In all analyses the implant cup has been modeled with the material properties of Titanium. The contact definition between the cup and bone was modeled to include a coefficient of friction.

Figure 2.12 illustrates the axisymmetric finite element model used with the different colors referring to the different bone materials and the titanium cup. For both the 2-D and 3-D analyses parametric models were created in order that different bone and implant cup geometries, material properties and boundary conditions could be evaluated. The assembly conditions involved inserting the cup into the bone to overcome interference, allowing the frictional effects to hold the cup in place and then to subsequently pull-out or twist-out the cup from the bone to establish dis-assembly loads.

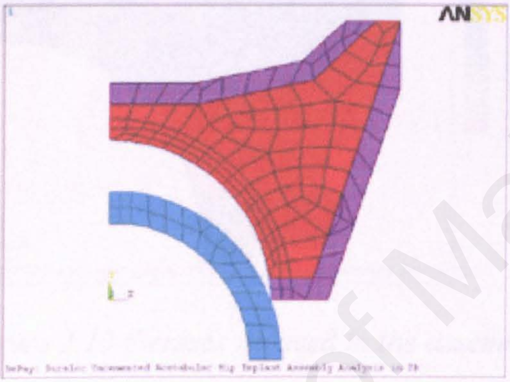


Figure 2.12: Axisymmetric finite element model

Figure 2.13 shows the stresses induced in the assembly due to the interference fit for the two dimensional axisymmetric analysis. The areas colored in grey illustrate the region of the bone which could be expected to yield during the assembly process.

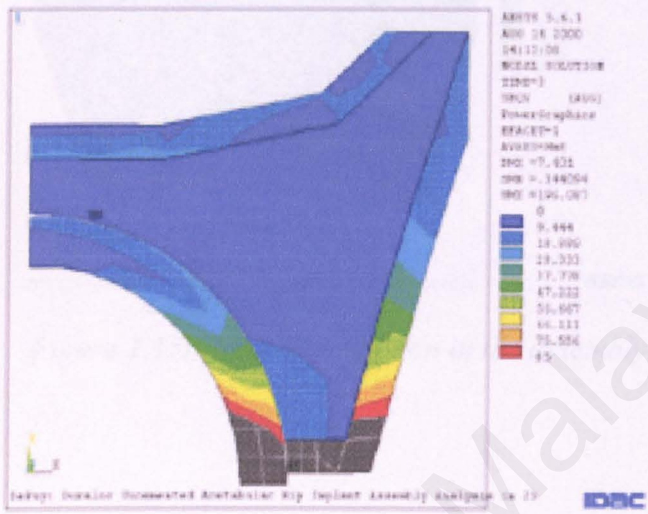


Figure 2.13 Stresses induced in the assembly

Figure 2.14 shows the equivalent three dimensional 180° sector finite element model. Two dimensional axisymmetric analyses are unable to evaluate the twist out loads for the assembly and hence the equivalent model needs to be analyzed in three dimensions.

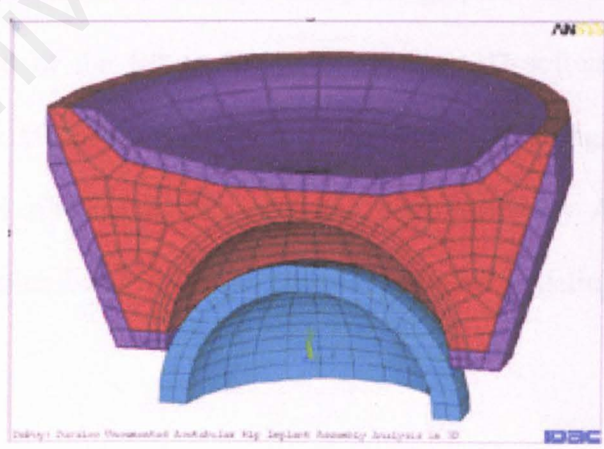


Figure 2.14: Finite element model

Figure 2.15 illustrates the stress distribution in the assembly after the interference has been taken up.

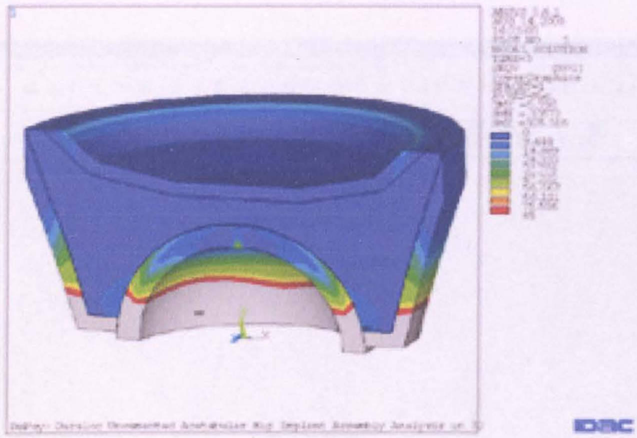


Figure 2.15: Stress distribution in the assembly

2.9 Review Software : Maya

Maya is relatively new 3D graphics development software. Although the latest version is Maya 5.0, the 4.5 Unlimited Edition is going to be used as the software tool for this simulation project. Maya 4.5 Unlimited also allows anyone to experience and learn the same 3-D software used to create such major computer graphic rich film productions as Star Wars and The Lord of the Rings. Maya is the first 3D software package to be bestowed with an Oscar. Maya offers a rich set of tools for modeling, animation, shape dynamics, rendering and simulation. The program was created by Alias|Wavefront, a division of Silicon Graphics Limited. Maya make simulation modeling easier and more effective.

2.9.1 User Interface of Maya 4.5 Unlimited

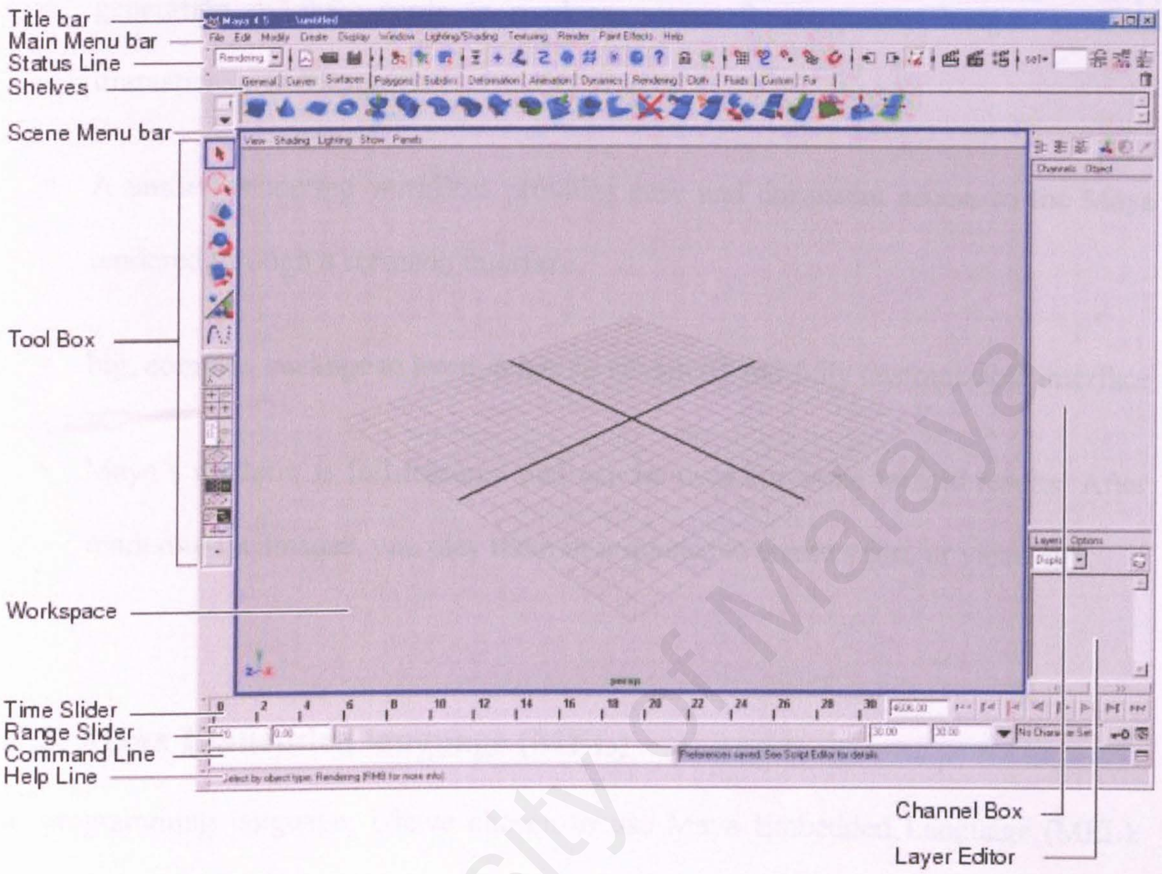


Figure 2.16: User interface of Maya 4.5 Unlimited

2.9.2 Advantages of Maya

- A new hardware rendering option takes advantage of the power of next-generation graphics cards to produce near software-quality images at often dramatically faster speed.
- A unified rendering workflow provides easy and consistent access to the Maya rendered through a common interface.
- big, complex package to learn, it has an advanced and fully customizable interface
- Maya's renderer is full-featured and can be used for some terrific results. After rendering the images, you play them in sequence to create a film or video clip.

2.9.3 Maya Embedded language (MEL)

For programming language, I have chosen to use Maya Embedded Language (MEL). MEL is a powerful command and scripting language that gives you direct control over Maya's features, processes, and workflow. As you select menu items or otherwise use the interface, Maya performs the operations by internally running MEL commands. In fact, much of Maya's user interface is built using MEL scripts and procedures. You can type the same MEL commands directly as a quick alternative to selecting menu items or doing other actions.

You can organize MEL commands into reusable script files that let you:

- automate tasks you might otherwise do more slowly or tediously with the user interface
- use additional Maya features
- create custom user interfaces
- perform specialized workflows
- create new effects

Although MEL is technically a scripting language, MEL has features that are worthwhile and easy to learn even if you have no programming experience.

3.0 Methodology

A methodology is a collection of procedures, techniques, tools and documentation aids which helps system developers in their task of implementing a new information system. It consists of a set of phases, which consist of a set of sub phases. This guides the developers to the choice of techniques at various stages in the project and helps them to plan, manage, control and evaluate info systems project.

The main objectives of following a methodology is to make the development cycle as efficient as possible, to complete development within lowest possible cost keeping the highest quality, and to achieve the fastest turn-around. Another important objective is to make future maintenance easier and faster. The development cycle for each and every project is some way unique, depending on system requirements and their unique operating environment. Design and development methodology also varies depending on the software, hardware technologies chosen.

3.1 The Prototyping Model

The prototype modeling methodology has been chosen to the development of this project because of its advantages. It allows all part of a system to be constructed quickly to understand or clarify issues and it also has the same objective as an engineering prototype, where requirements or design require repeated investigation to ensure that the developer and user have a common understanding both of what is needed and what is proposed.

One or more of the loops for prototyping requirements, design or the system may be eliminated, depending on the goals of the prototyping. However, the overall goal remains the same; reducing risk and uncertainty in development.

Steps are taken in implementing the prototyping methodology in this system development:

1. Prototyping begin with a nominal set of requirements which are gathered through various discussions with the supervisor
2. Then, alternatives are explored by having interested parties look at possible screens, reports and other system output that are used directly by the users.
3. When the decision is made, then the requirements are revised and process of design is started.
4. Design is revised until developers and users are happy with the result.
5. Finally, the system is coded and alternatives are discussed, with the possible iteration through requirements and design again.

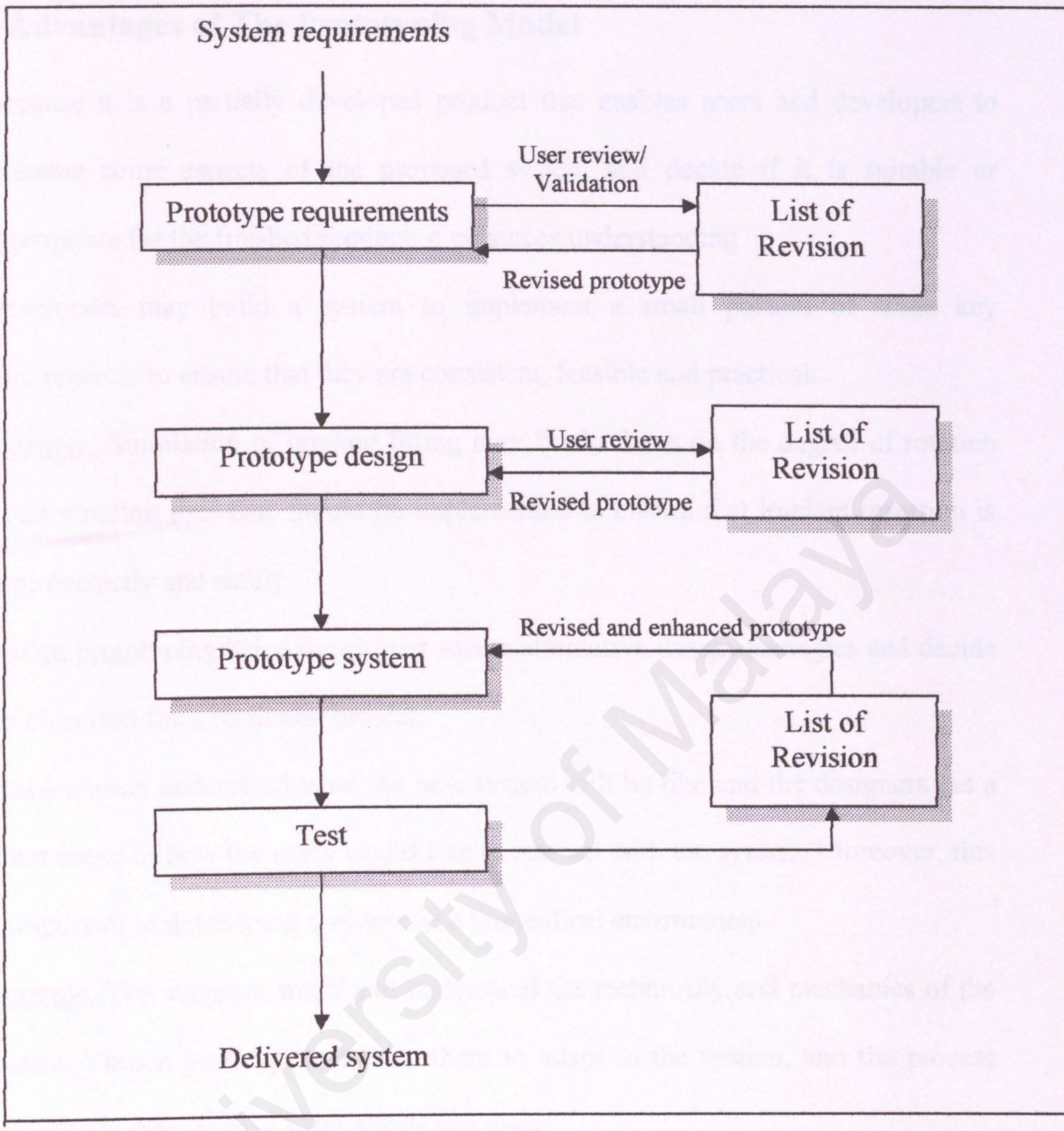


Figure 3.1: The Prototyping Model

3.1.1 Advantages of The Prototyping Model

- ✓ Because it is a partially developed product that enables users and developers to examine some aspects of the proposed system and decide if it is suitable or appropriate for the finished product, it enhances understanding
- ✓ Developers may build a system to implement a small portion of some key requirements to ensure that they are consistent, feasible and practical.

  <u>Example:</u> Simulation of implant fitting may firstly focus on the degree of rotation transformation axis that should be implemented to ensure that implant insertion is done correctly and safely.
- ✓ Design prototyping helps developers assess alternative design strategies and decide which is best for a particular project.
- ✓ Enables users understand what the new system will be like and the designers get a better sense of how the users would like to interact with the system. Moreover, this is important in developing a system in a biomedical environment.

  <u>Example:</u> The surgeons might not understand the technically and mechanics of the system. Thus a prototype will help them to adapt to the system, and the process loops allow them to give suggestions and views.
- ✓ Developers can evaluate the level of understanding of the users about the system. Therefore, any disagreements in the requirements are registred and fixed well before the requirements are officially validated during system testing.
- ✓ Prototyping is very useful for validating the implementation of all the requirements needed and to verify that each function works correctly.

3.2 Information Gathering Method

Method of gathering information regarding a system is necessary in order to establish understanding of the state and future requirement on the system study and provide the groundwork for the system design.

There is no underlying standard or procedure to be followed strictly as each single project is unique and data-gathering may be vary to suit the needs of each particular project. However, there are a certain number of methods that are commonly used in gathering-information such as collecting hard data like written documents or reports, interviewing, using questionnaires, observation and sampling. The main data sources for system analysis were written documents, reference books, observation and other sources from the Internet.

I. Internet Surfing

Internet is being used to seek information about the latest technologies, existing system that similar to Simulation of Implant Fitting Hip Bone and information related to this project. Site visits and joining related newsgroups on the World Wide Web (www) like are important to obtain a vast amount of up-to-date information from all around the world.

II. Book and References

Book and references are used to get the information that needed to develop the system. This including information from information system references, development tools references, programming references and database references.

Faculty of computer sciences documents room has a lot of senior's thesis that can be as a guideline for to write the thesis report. The format type of the report, organization of the heading and the content of the report can be referring from senior's thesis.

III. Monograph

A lot of published literatures were read in order to gather information of the user's needs. This is important especially to obtain system development needs and technical issues of the proposed system. All these can be categorized into the printed material (especially books and journals), and non-printed materials, such as electronic documents. Useful information has been found in Chips and PC Magazine and In-Tech, which is published by a local newspaper, The Star. This entire magazine provides the latest news about technology in the computing environment.

IV. Discussion with Supervisor

A discussion with supervisor has been practiced from time to time in order to get help and advices during the development of the project.

3.3 System Analysis

After all the technologies have been reviewed and analyzed, the most suitable and appropriate tools for developing the system are identified and selected. The tools to be selected include the development software as well as the entire platform on which the development of the project is occurred.

The main purpose of this phase can be concluded as listed below:

- Identifying major components to be included in the system to resolve system requirements by collecting user needs and by
- To learn how a similar system functions correctly and accurately.
- Ensure that the software development methodology proposed is suitable for analyzing and developing the system.
- To determine hardware and software specifications to be used.

A requirement is a feature of the system or a description of something the system capable of doing in order to fulfill the system's purpose. This can be categorized into two types: functional requirements and non-functional requirements.

3.3.1 System Functional Requirements

Functional requirements describe an interaction between the system and its environment. These are statement s of services the system should provide, how the system should react to particular inputs and how the system should behave inn particular situations. In some case, the functional requirements may also explicitly state the system should not do. Functional requirements for this system are:

1. **3D models**

   3D models of the human femur bone and the implant of the hip are needed. These elements will be acquired from earlier projects done previously. The 3D models should be in computer graphics 3D image types such as IGES, STL , MB or any that is compatible with Maya 4.5.

2. **Location of implant insertion**

   User should be able to see the point location of implant insertion to simulate the fixing process to the femur bone.

3. **Viewing Options**

   User may choose to view from different angles. This can be done using the mouse and "Alt" button and view the static model orthographically, isometrically and also perspectively.

3.3.2 System Non-functional Requirements

Non-functional requirement describes a restriction on the system that limits our choice for constructing a solution to the problem they including timing can constraints, constrains on the development process and standards. Non-functional requirements that are need for this system are:

1. **Types of specimens**

   Only an adult human femur bone and implant of hip will be used. Therefore, there will be no database of these specimens, including types of hip problem and solutions or outputs of the simulated surgery.

2. **Reliability**

   It has to be of high reliability because we are going to deal with live patients in real-time surgeries and the simulation must be able to be delivered correctly and accurately, or fatal post-surgery effects could arise.

3. **Consistency**

   Not only produce outputs which are correct and precise, but consistent all the time. This will increase the reliability factor as well.

4. **Response time**

   Two arguments regarding this issue; (1) If the system is used as a learning tool for students, time might not be a problem; (2) If a surgeon needs to operate on a patient, the system must be able to deliver the correct simulation in time with the event

3.4 Software Requirements

Software Development:

- ✓ Maya 4.5 Unlimited

Operating System requires running this program:

- ✓ Windows XP Professional Edition

Scripting that is using in software development:

- ✓ Maya Embedded Language (MEL)

Documentation was done with:

- ✓ Microsoft Office Tools 2000 (Word, Power Point, Excel)
- ✓ Microsoft Project

3.5 Hardware Requirements

Simulation of Implant Fitting Hip Bone was developing with this hardware:

- ✓ 367MHz
- ✓ 160 MB RAM
- ✓ 10GB hard disk
- ✓ 800 x 600 Screen Resolution
- ✓ AOPEN CD-RW CRW2440
- ✓ VGA/SVGA monitor
- ✓ Mouse & Keyboard

3.6 Conclusion

This chapter explains the methodology that will be used in developing the system. In order to produce a more efficient and better quality system, this project will be develop by implementing the prototyping methodology. It also includes the system analysis section where careful analysis and research has been conducted to determine the feasibility of the system and what is required of it. Various techniques of information gathering such as monograph, internet source, previous thesis and discussions with the lecturer has been practiced. This chapter shows how the system developer interprets the important features that should be implemented in the real system.

4.0 System Design

System design is a process of devising and documenting the overall architecture for a system. It includes identifying the major components of the system, specifying what they are to accomplish, and establish the interfaces among components. Design is the first step in the process of transforming the requirements into a close representation of the eventual functional software. This project consists of two components. They are the architectural and the user interface design.

4.1 Architectural design

Architectural design may be based on a particular model or style. Different designers approach the architecture design process in different ways. The structure chart that be using in this system were system structuring and modular decomposition.

- ***System structuring***

  The system is structured into a number of principal sub-systems where a sub-system is an independent software unit. Communications between sub-systems are identified.

- ***Modular Decomposition***

  Each identified sub-system is decomposed into modules and its interconnections.

4.1.1 Structure Chart

Structure charts are used for procedural programs to illustrate the following information about a program in a visual format:

- Partitioning of a program into named modules (functions)
- Top-down hierarchy and organization of modules
- Linkages between modules
- Flow of data, control or exception information

In my system, there will be four main modules. They are static hip module, dynamic implant module, simulation and help module.

1. Static Hip Module

This module gives a chance to learn about static image of the hip bone. It divided into two sub modules which are male and female hip bone. This male and female hip bone can be categorized as adult or kid bone. (See figure 5.2)

2. Dynamic Implant Module

The module contains three sub modules. Users can be visualizes 3-D graphics of implant type from several perspectives like acetabular shell, polyethylene liner and femoral head. (See figure 5.2)

3. Simulation

The user has to choose the suitable technique of simulation in order to fitting the implant to the hip bone. .

4. Help module

This module lists out the entire control button used in system. It explains to user the usage of each control buttons.

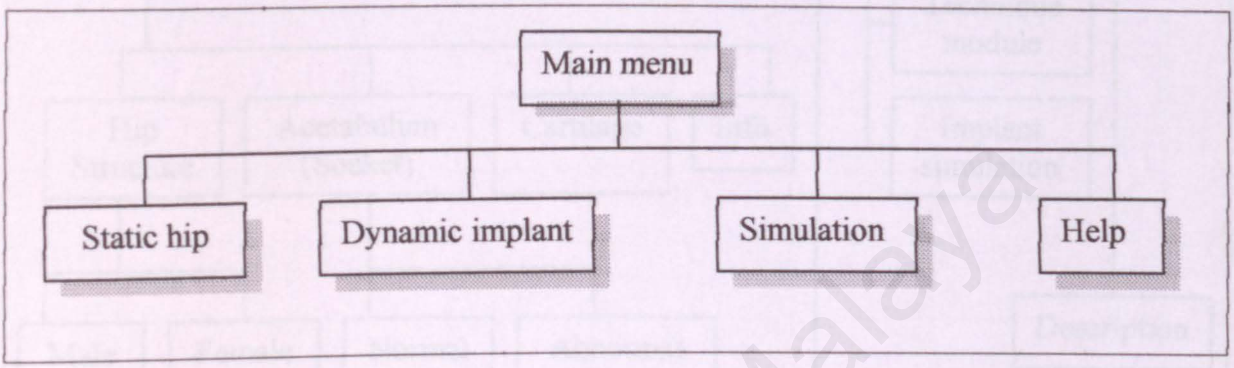


Figure 4.1: Main system structure chart (Main Menu)

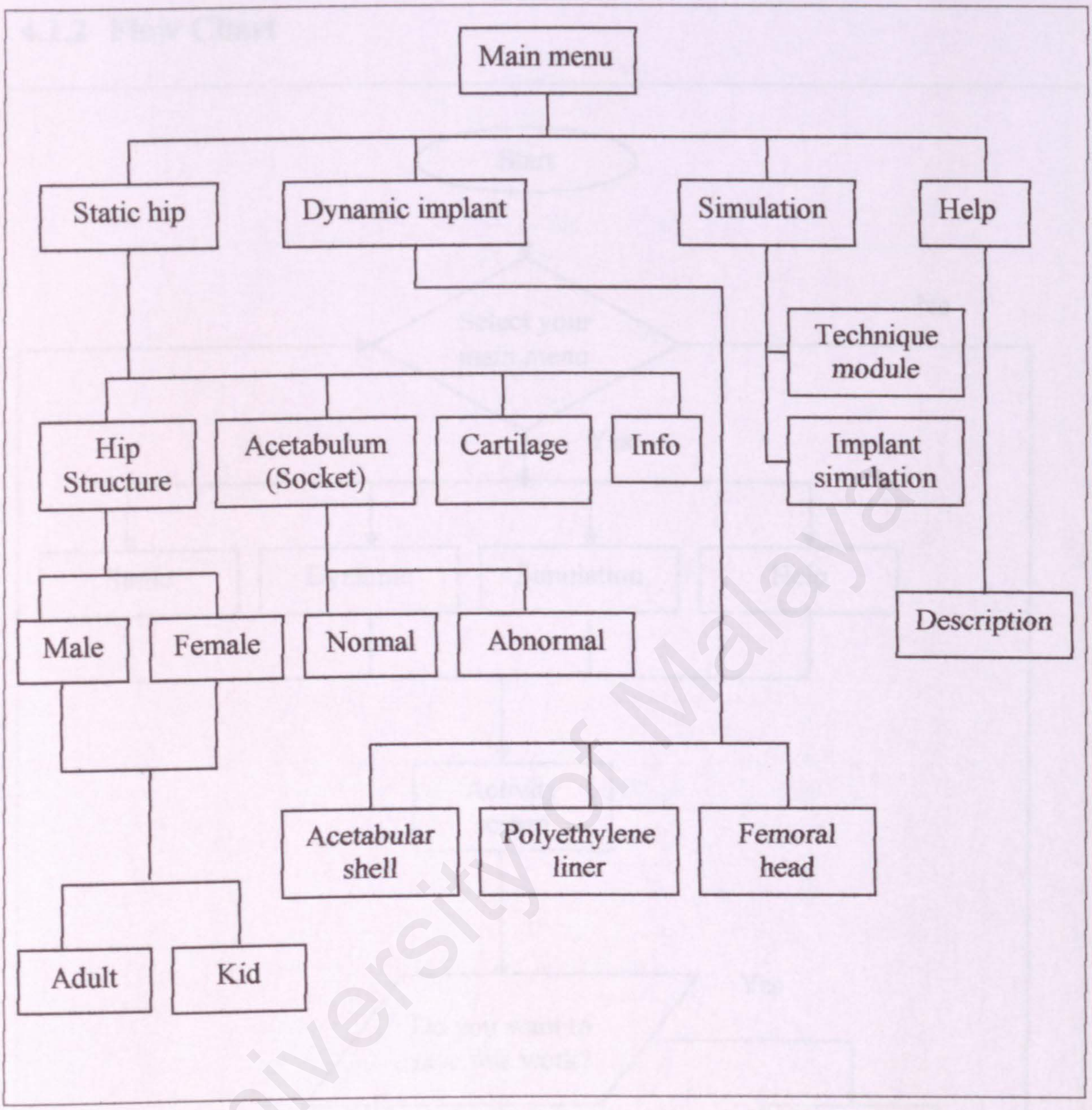


Figure 4.2: Structure chart of Simulation of implant fitting hip bone using Maya

4.1.2 Flow Chart

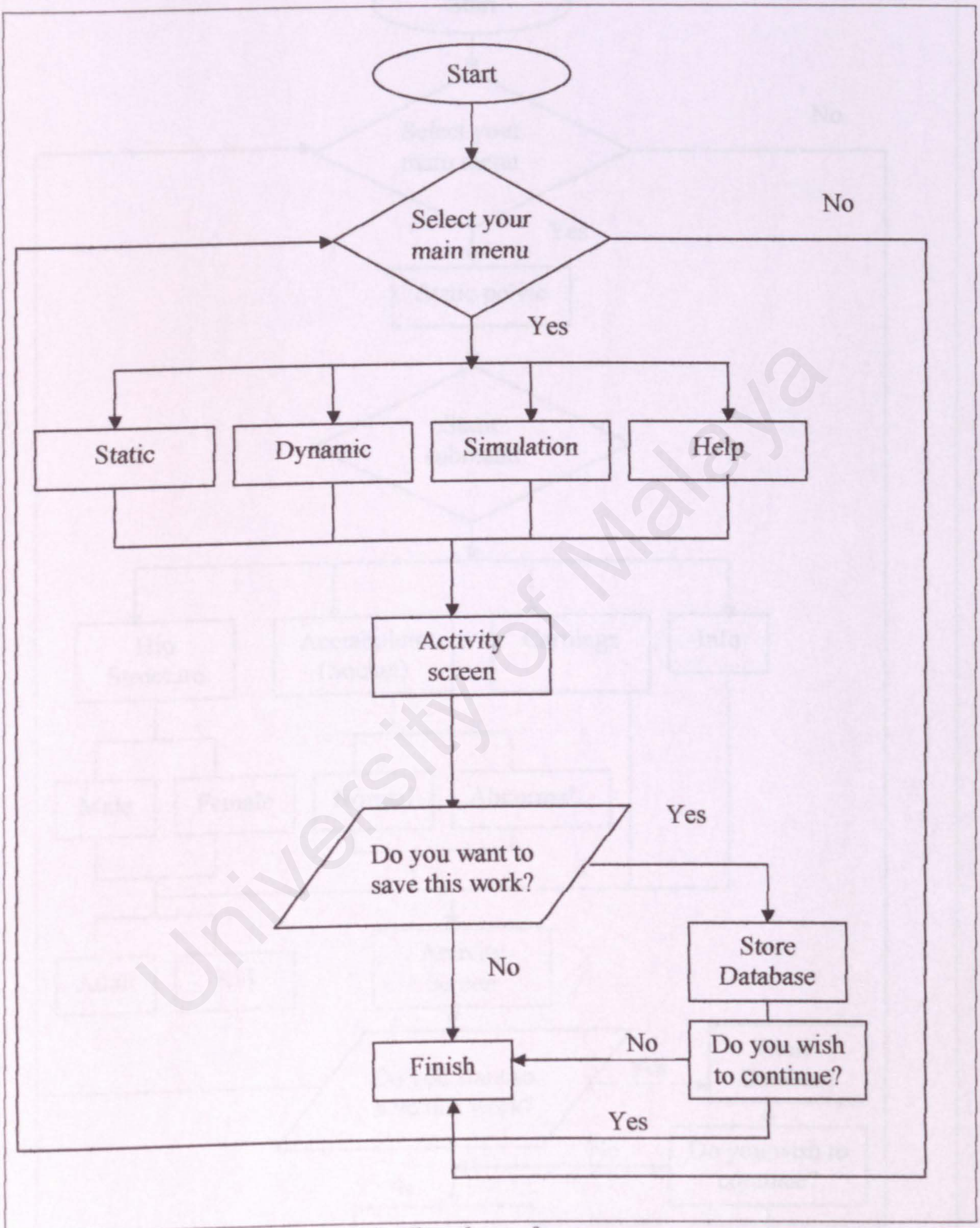


Figure 4.3: Flowchart of main menu

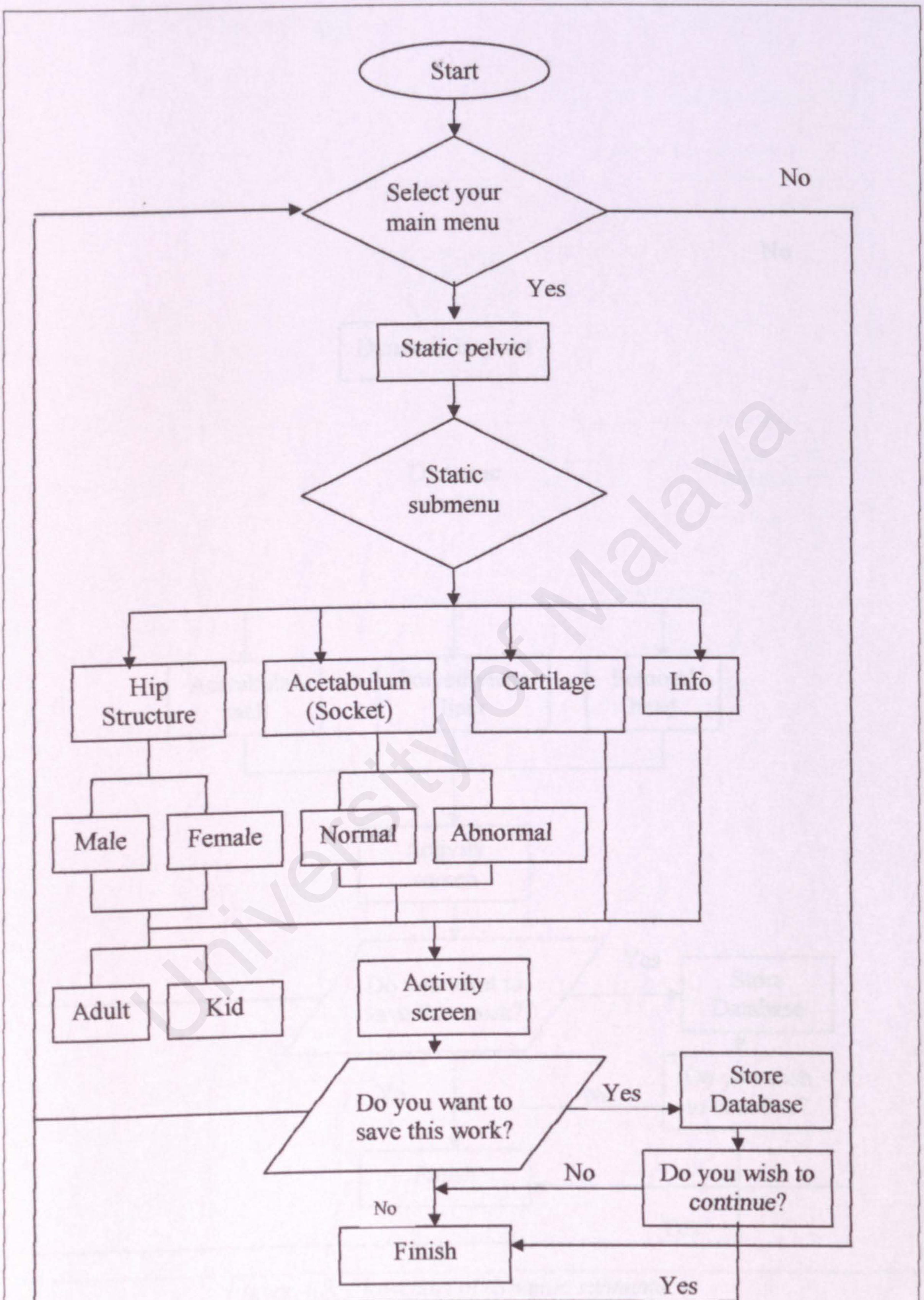


Figure 4.4: Flowchart of static submenu

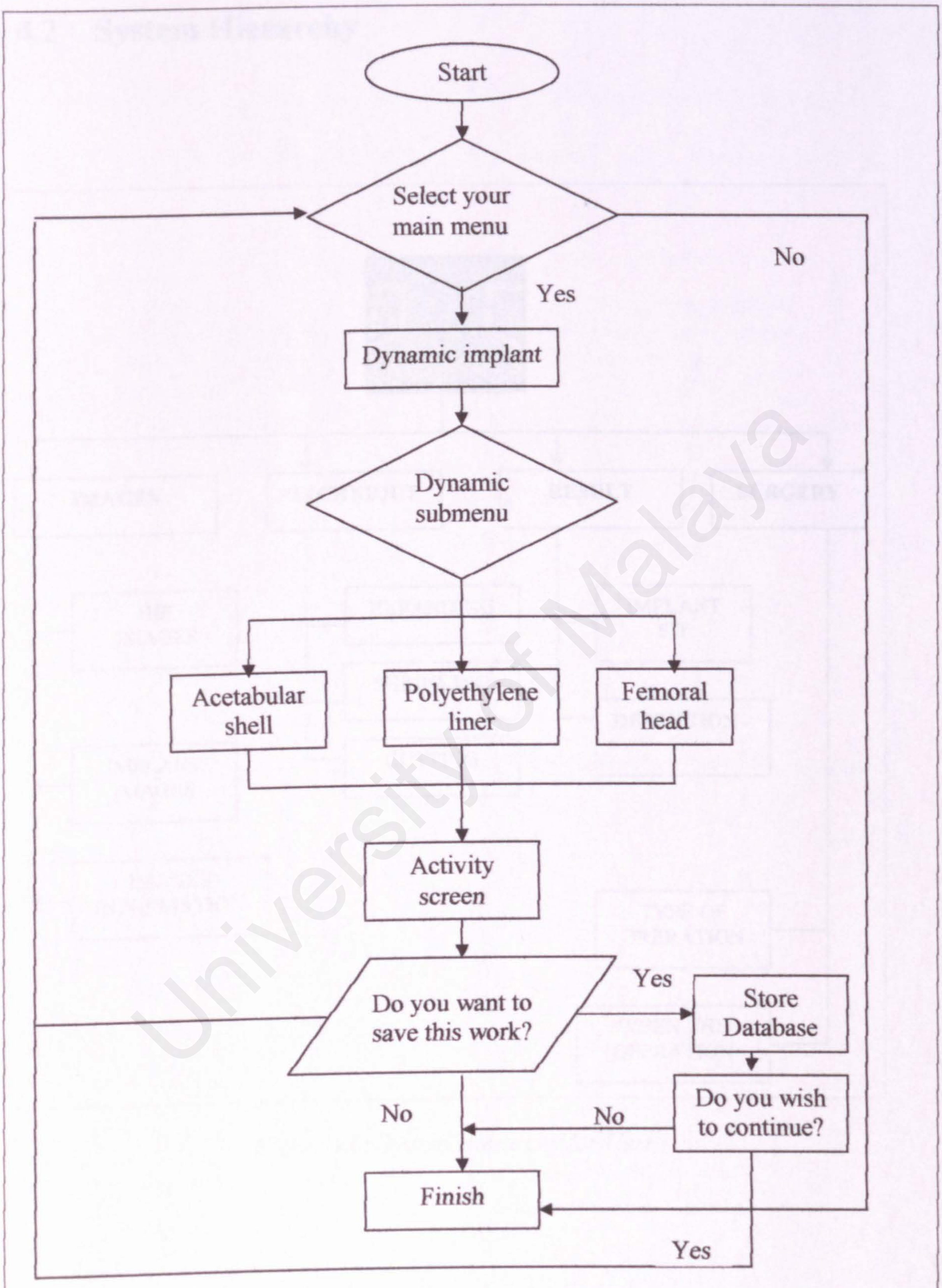


Figure 4.5: Flowchart of dynamic submenu

4.2 System Hierarchy

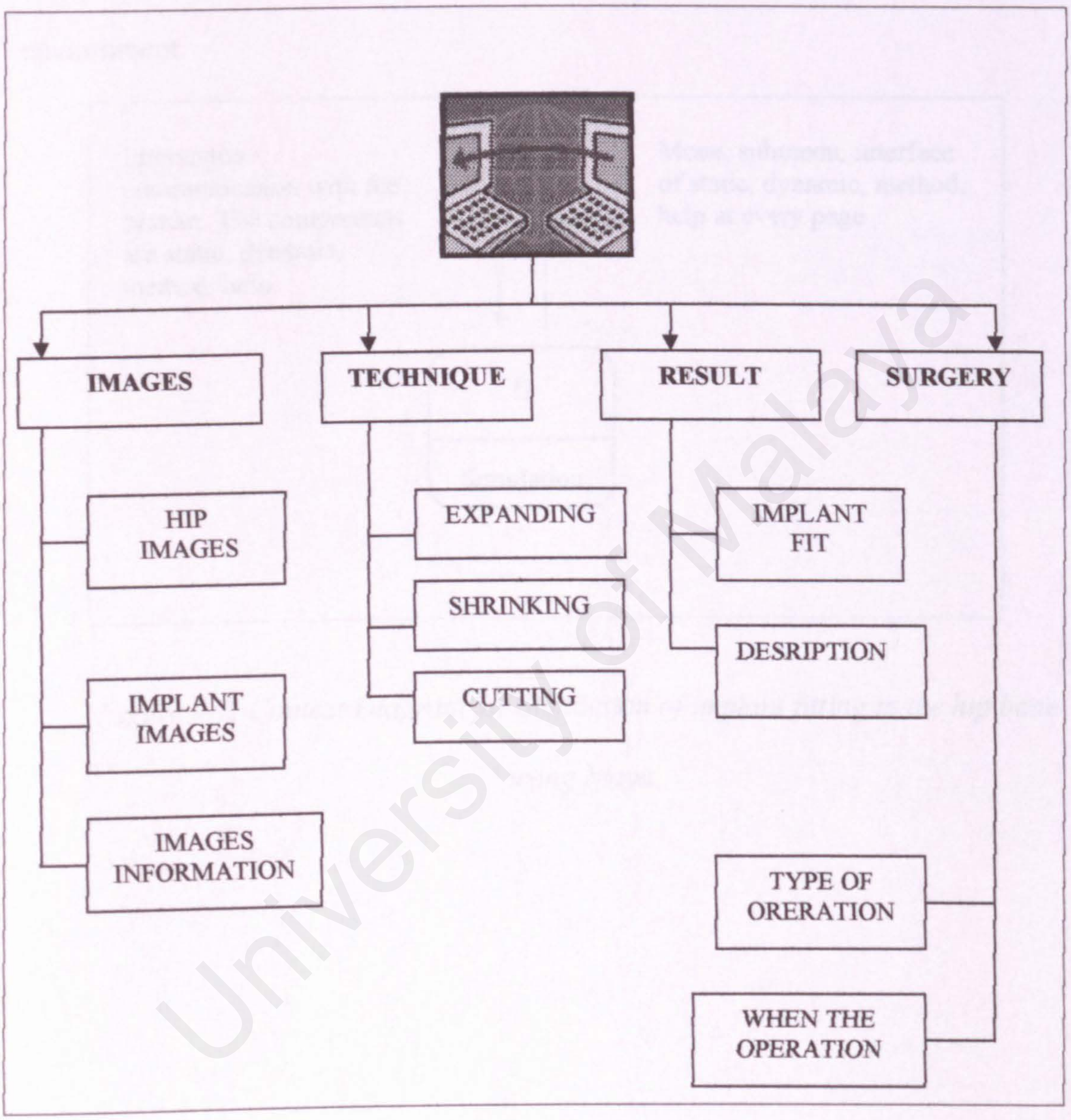


Figure 4.6: System Hierarchy for User

4.3 Context Diagram

A system context diagram is constructed to establish initial project scope. This simple data flow diagram shows only the system's main interfaces with its environment.

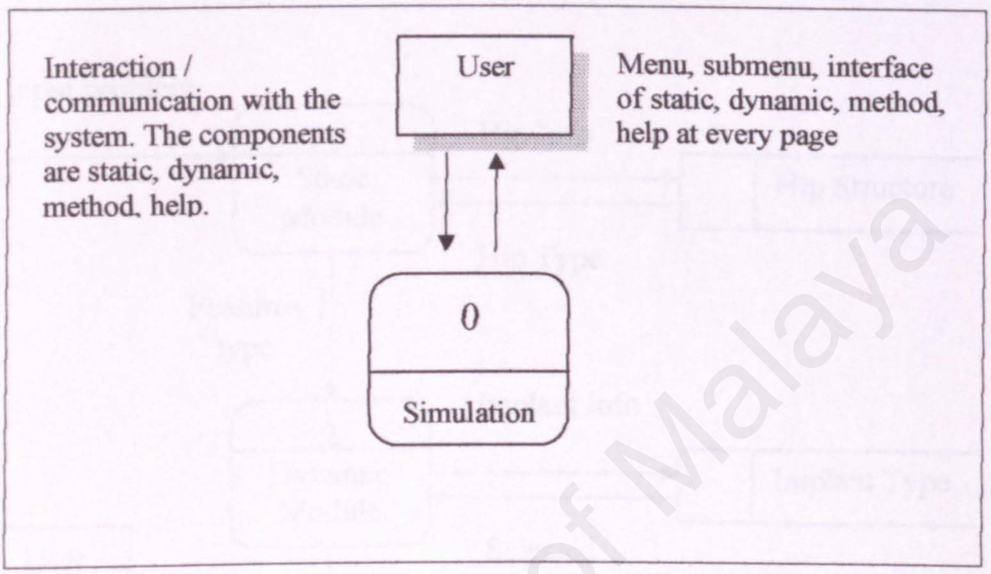


Figure 4.7: Context Diagram for Simulation of implant fitting in the hip bone using Maya

4.4 Data Flow Diagram (DFD)

Data flow diagram is a tool that depicts the flow of data through a system and the work or processing performed by that system.

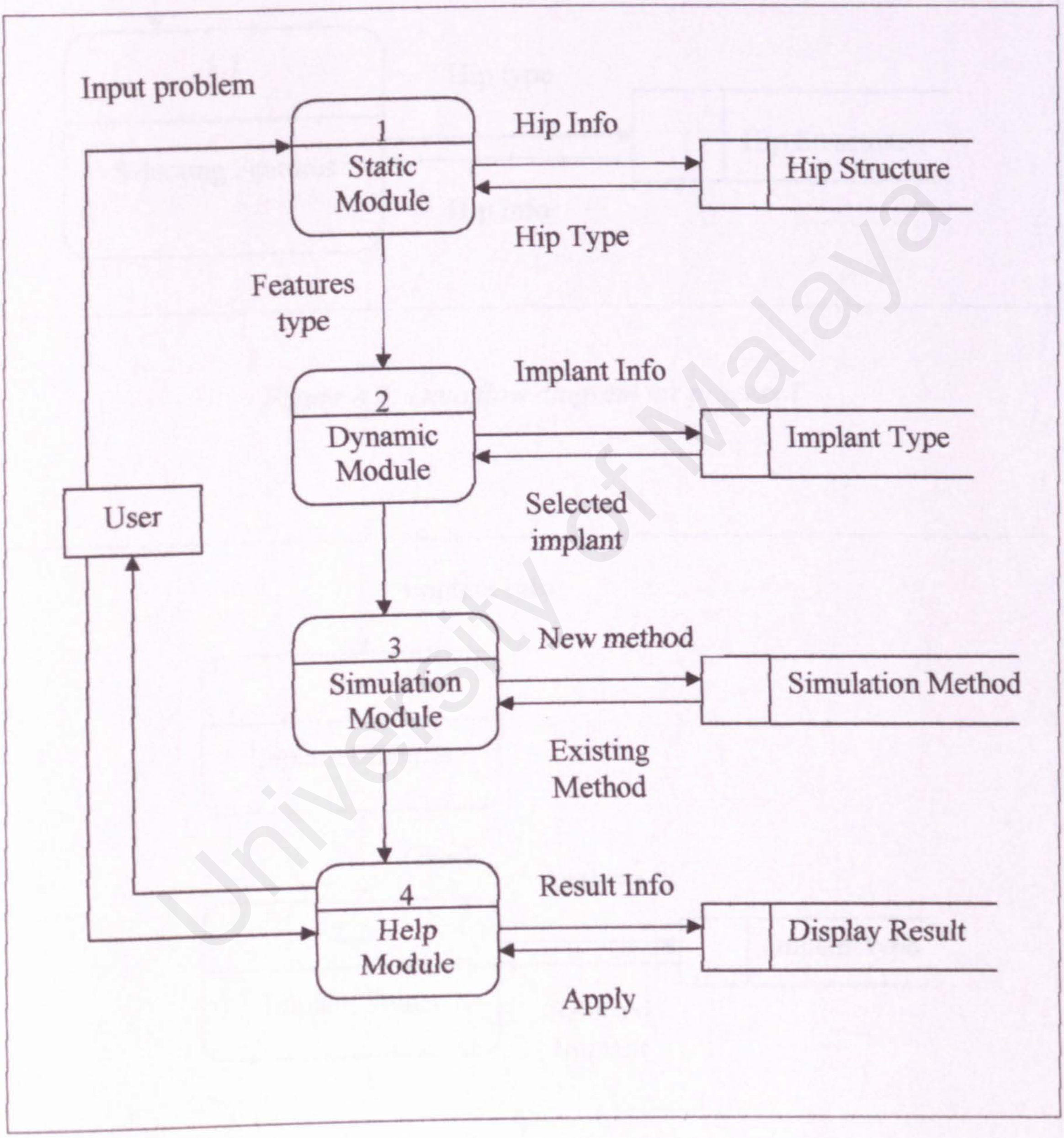


Figure 4.8: Data flow diagram for Level 0

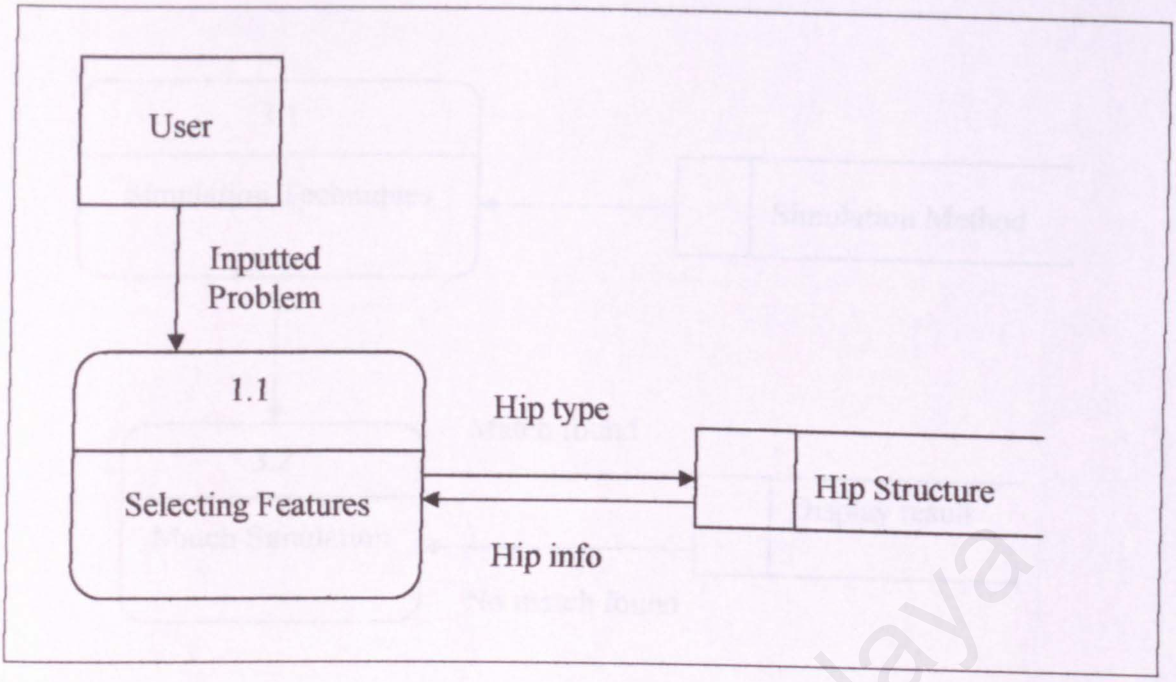


Figure 4.9: Data flow diagram for process 1

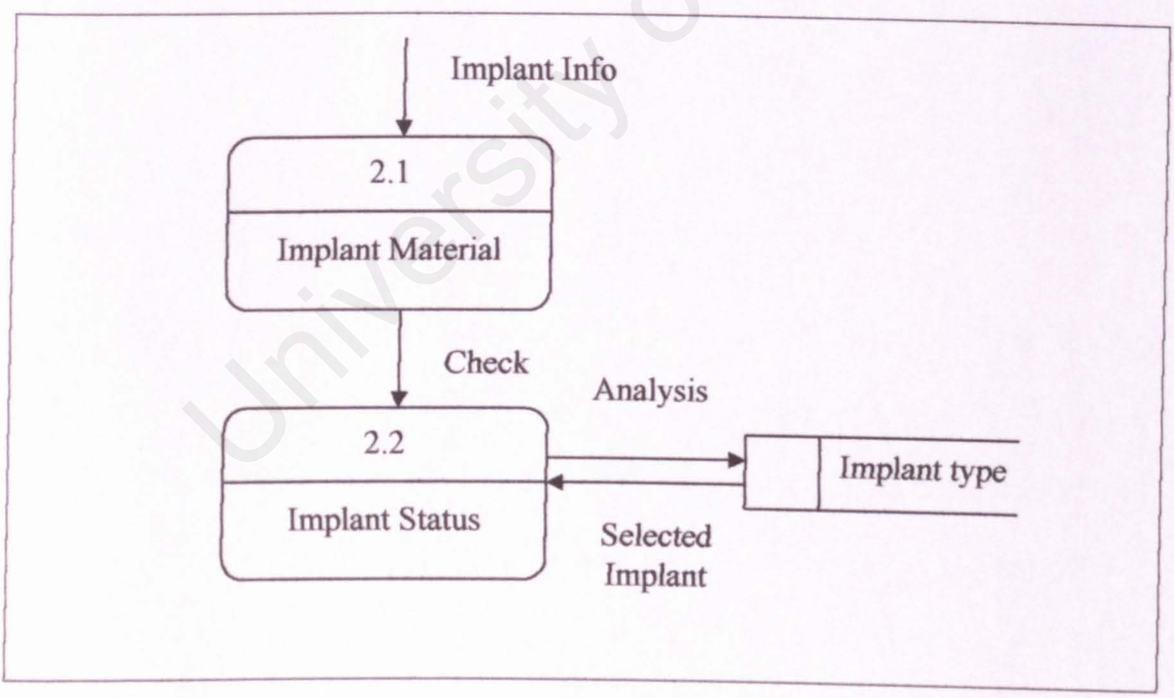


Figure 4.10: Data flow diagram for process 2

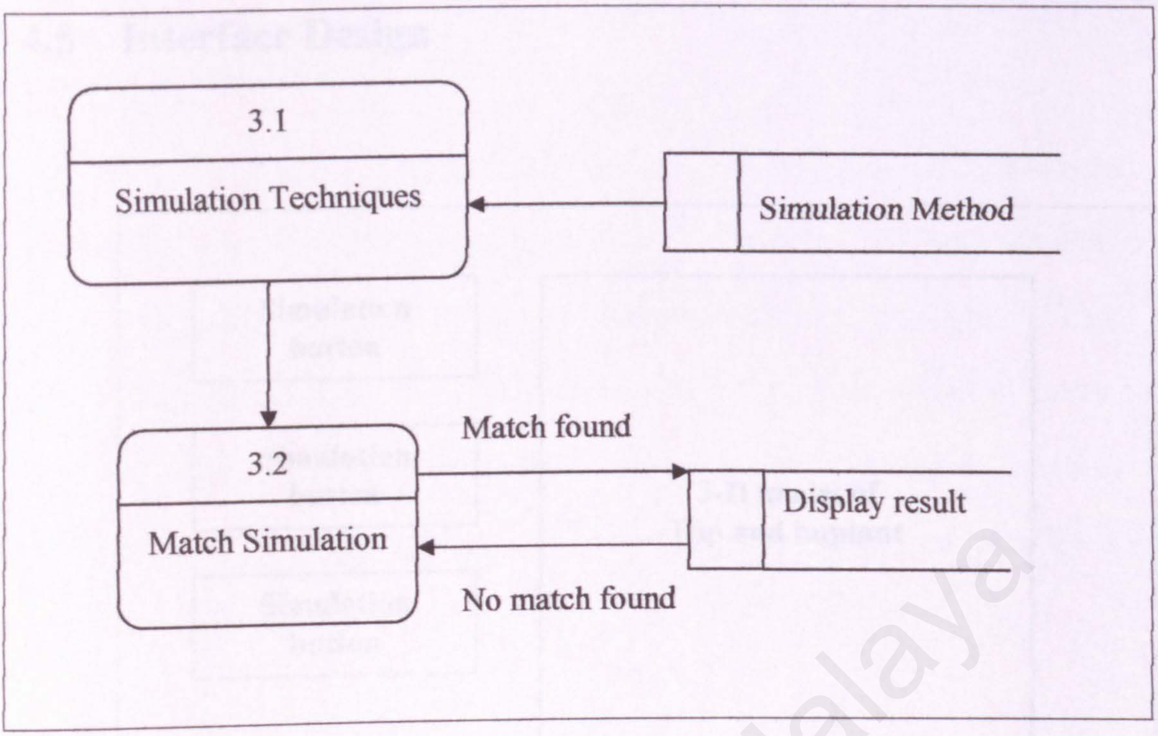
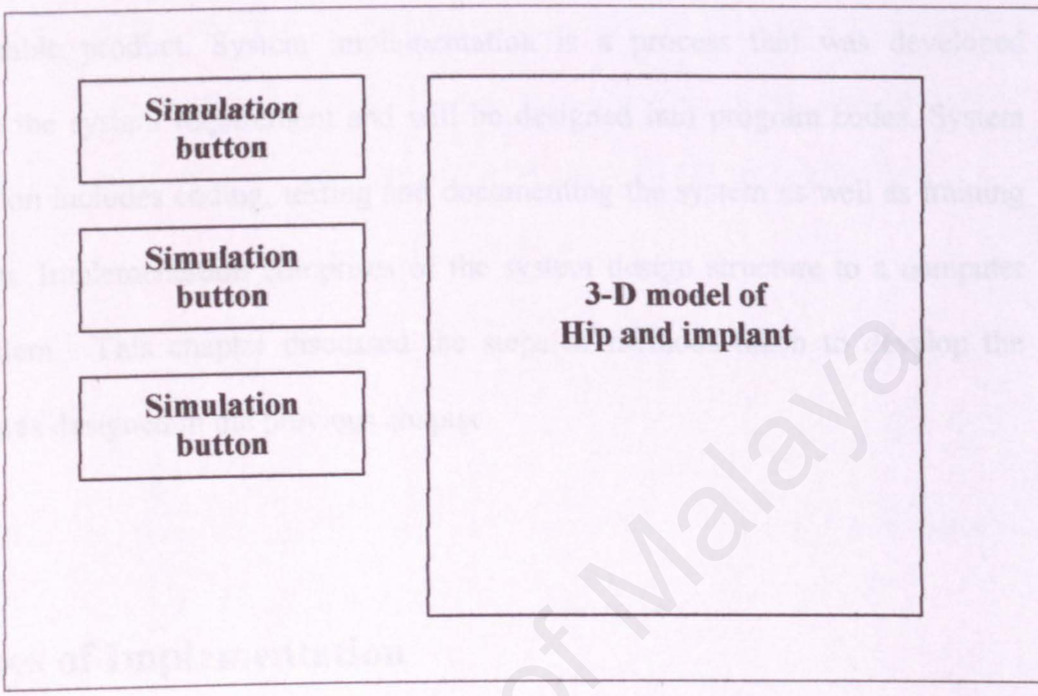


Figure 4.11: Data flow diagram for process 3

4.5 Interface Design



4.7 Summary

This chapter will discuss about the design of the system. Each stage in the process has been elaborated into a more details sub process. Data Flow Diagram (DFD) will be used to describe the facets in the proposed system where each of the modules in the system has been drawn out. The details represented in this chapter will serve as a reference and important guidance for the system development phase as well as the system implementation and maintenance phase.

5.0 System Implementation

In this phase, the system requirements and design model of a system will be converted into a workable product. System implementation is a process that was developed according to the system requirement and will be designed into program codes. System implementation includes coding, testing and documenting the system as well as training the end users. Implementation comprises of the system design structure to a computer readable system. This chapter discussed the steps of methods taken to develop the system that was designed in the previous chapter.

5.1 Types of Implementation

The system will be evolved from scratch design to a run able application. There are several implementations for this system.

- Conversion Options
- Data Formats
- Skinning

5.1.1 Conversion Options

Data regarding the femur and its implant were given in the form of point clouds data. Since there is no facility in Maya to automatically convert all the data into something intended by this thesis, (except probably through custom made plug-in development or extensive mel-scripting), various other software were chosen to do the conversions.

5.1.2 Data Formats

Details of the conversion were taken into consideration to mimic the real industry practice. Among those was the significance of formats studied;

- Point clouds are the standard result of objects scanned into 3D model using various industry recognized tools such as MicroScribe 3D digitizing products from Immersion.
- IGES format is the standard in solid modeling CAD/CAM and simulation industry.
- DXF is the standard in architectural world.
- VRML for virtual reality modeling and simulation.
- Others are OBJ and 3DS formats from AliasWavefront and Discreet respectively, which are used extensively in surface based modeling package in effects and digital content creation by professional around the world.
- Another format is PLY format which are extensively used by academic institutions in North America and Europe.

Data in point clouds form was imported into *Rhinocerous* software package to construct the lines connecting the dots into NURBS lines. The lines were constructed by connecting the dots using specified plane of either XY plane, YZ plane or XZ plane. The connected dots which are now form continuous lines in the direction of the chosen plane then exported in IGES format from *Rhinocerous* package.

Femur bone file in IGES format was imported directly into Maya software package. Total lines constructed were then found to be more then 60,000 NURBS line altogether which slowed the system down considerably. The implant on the other hand was imported into GeoMagic software package and its surfaces were reconstructed using the lines. Since GeoMagic itself is a solid modeling tool, it basically has no problem in handling the data. The implant was then exported in OBJ format, which created an implant model, surfaced using triangles.

Below is the figure of femur and implant as seen on the Maya Graphical User Interface 1:

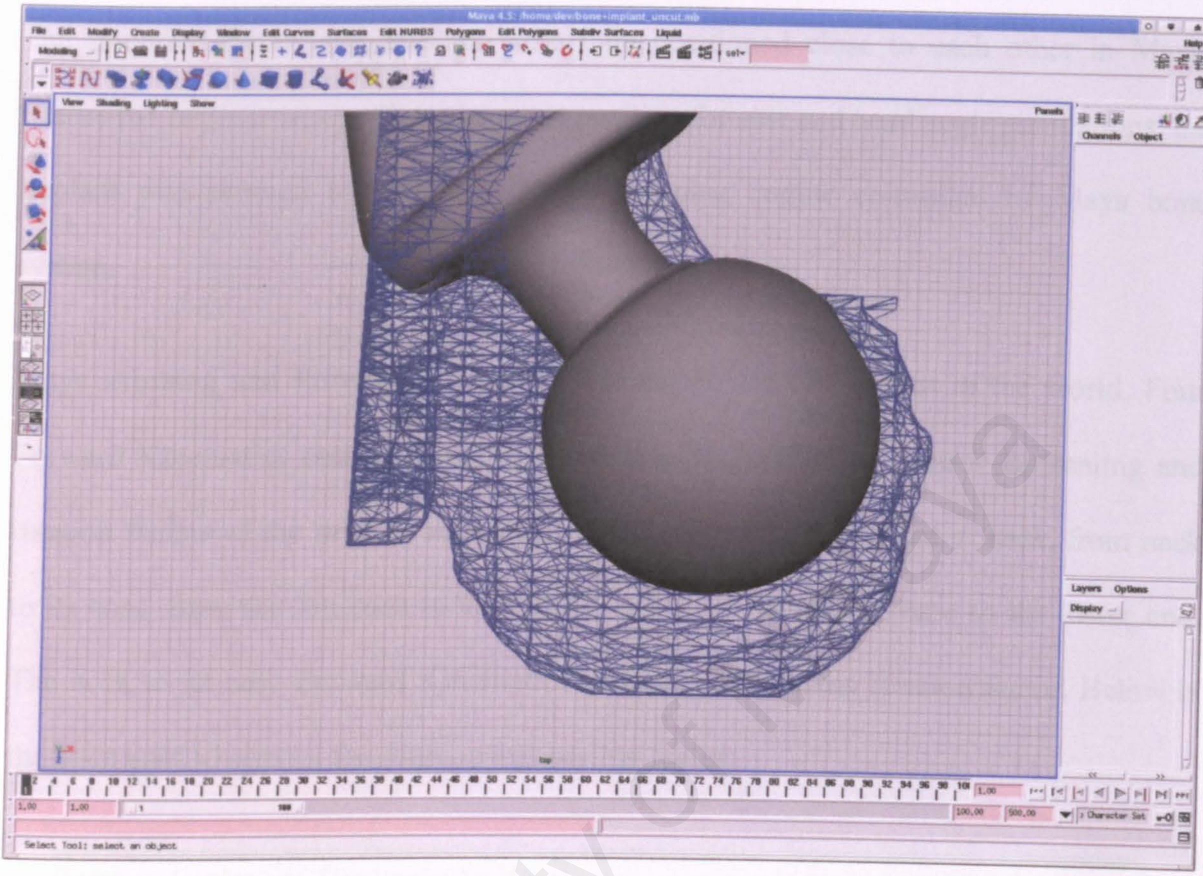


Figure 5.1: Femur and Implant as seen on the Maya Graphical User Interface

5.1.3 Skinning

The imported femur and implant were then positioned close to each other in Maya. Before the implant was put into the exact position for size and head angle simulations, the implant was skinned using Maya default skinning engine controlled by Maya bone system.

Maya skinning and Forward Kinematics system is one of the best in the world. Four Forward Kinematics controls were inserted into the implant to control the scaling and rotation factors of the implant subsection. Those areas are from head to neck, from neck to its base, from the top base to its middle, and from the middle base to the lower end. The neck to its base Forward Kinematics was controlled using rotation factor. Below is the code used to control the rotation and scaling factor:

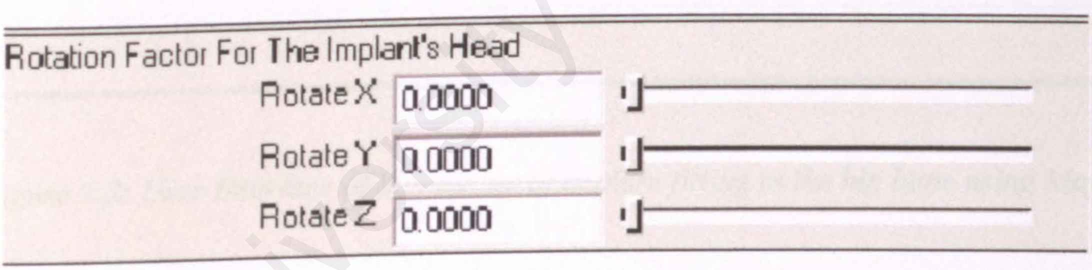


Figure 5.2: code used to control the rotation and scaling factor

5.2 User Interface

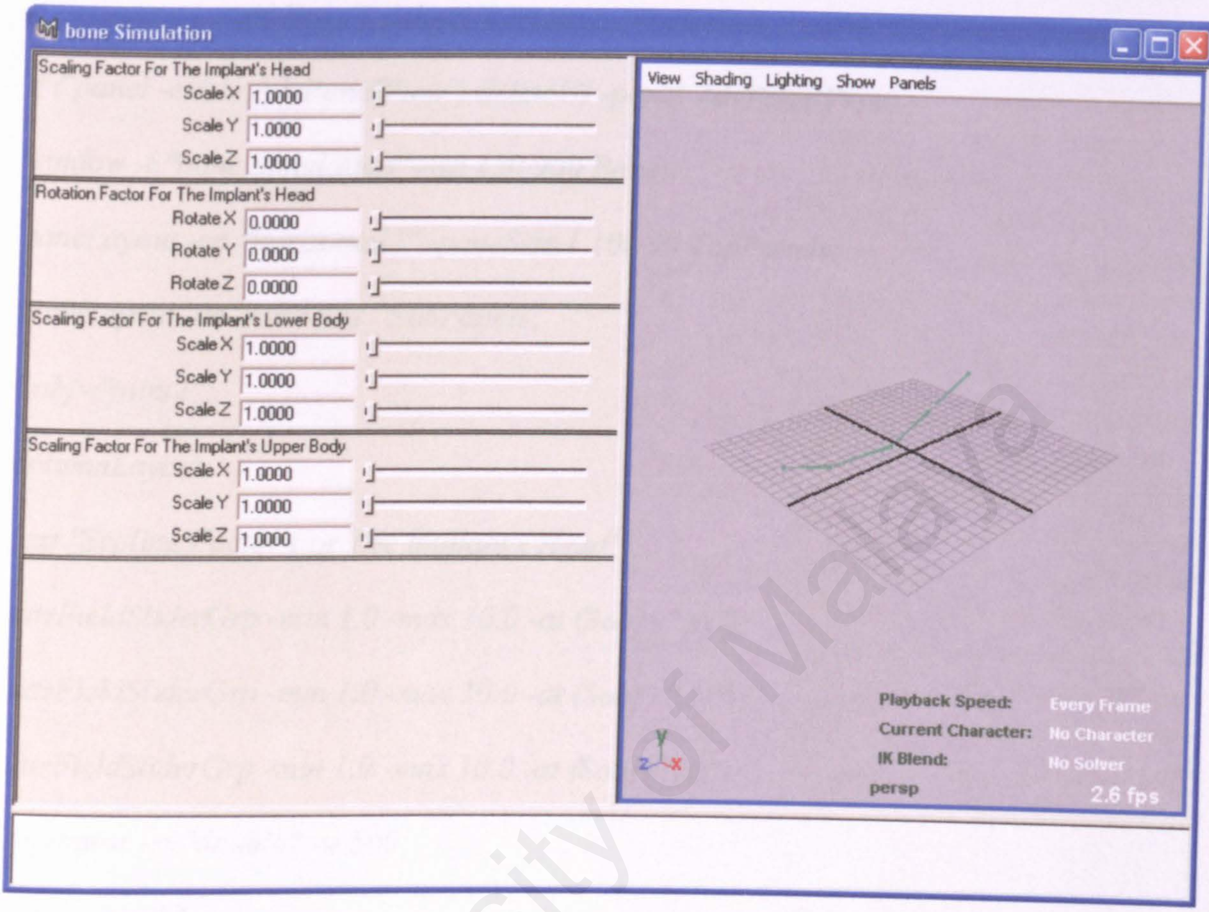


Figure 5.3: User Interface of Simulation of implant fitting in the hip bone using Maya

5.2.1 Scripting for the User Interface

```
if (`window -exists Bone`) deleteUI Bone;
if (`panel -exists AdvPanelView`) deleteUI -panel AdvPanelView;
window -t "bone Simulation" -wh 450 900 Bone;
paneLayout -cn "horizontal2" -paneSize 1 100 90 TopPanels;
paneLayout -cn "vertical2" SubPanels;
$obj="joint2";
columnLayout;
text "Scaling Factor For The Implant's Head";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sy");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sz");
separator -st "double" -w 500;
$obj="joint1";
columnLayout;
text "Rotation Factor For The Implant's Head";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".rx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".ry");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".rz");
separator -st "double" -w 500;
$obj="joint4";
columnLayout;
text "Scaling Factor For The Implant's Lower Body";
```

```
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sy");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sz");
separator -st "double" -w 500;


columnLayout;
$obj="joint5";
text "Scaling Factor For The Implant's Upper Body";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sy");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sz");
separator -st "double" -w 500;


setParent SubPanels;


modelPanel AdvPanelView;
modelEditor -edit -displayAppearance smoothShaded AdvPanelView;
setParent SubPanels;
setParent TopPanels;


window -e -wh 800 600 -topLeftCorner 50 50 Bone;
showWindow Bone;
```

5.2.2 Comparison's before and after the implant head scaling

Below are two comparisons of before and after the implant's head scaling.

<u>*Before:*</u>

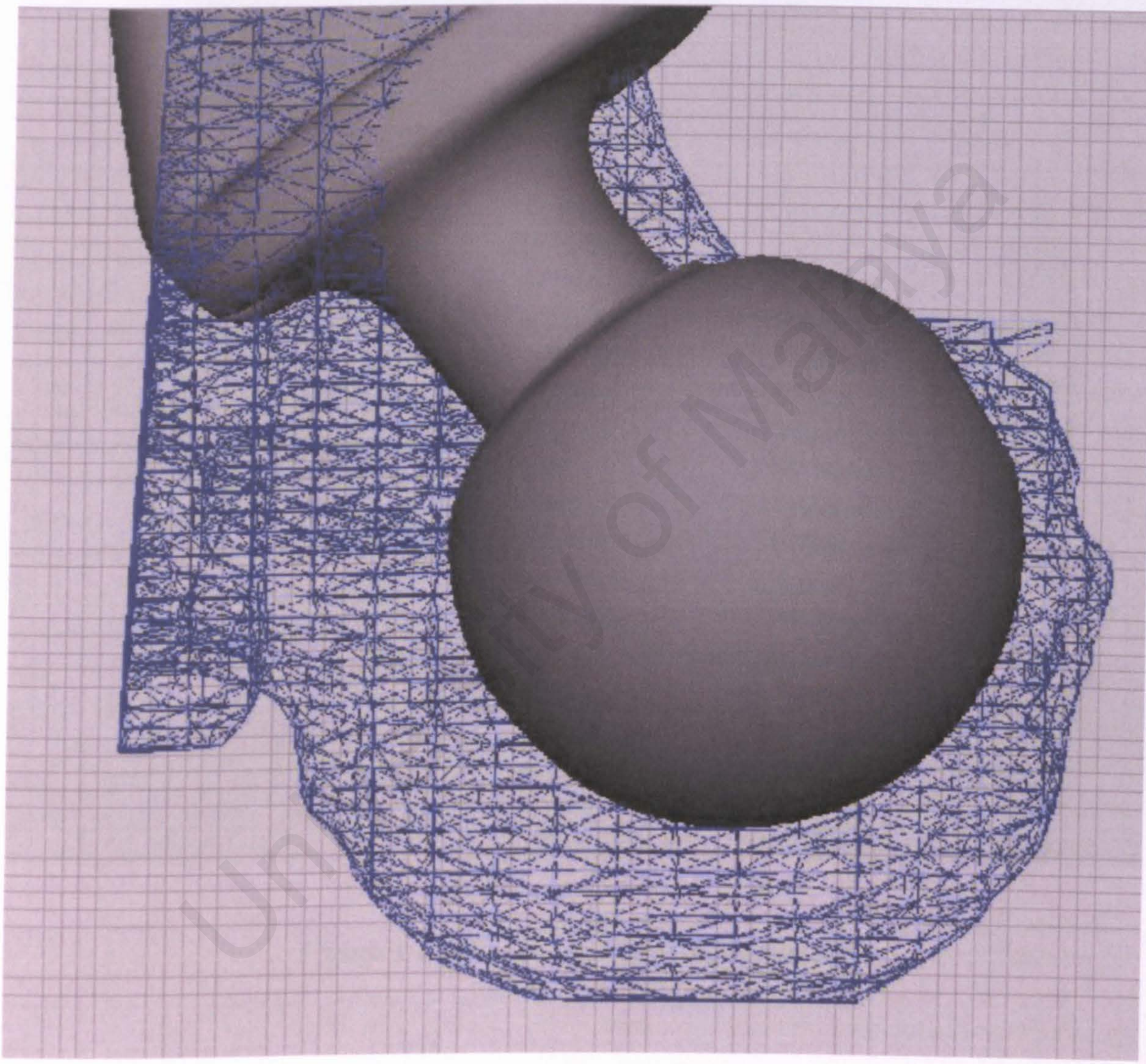


Figure 5.4: Before the implant's head scaling

After:

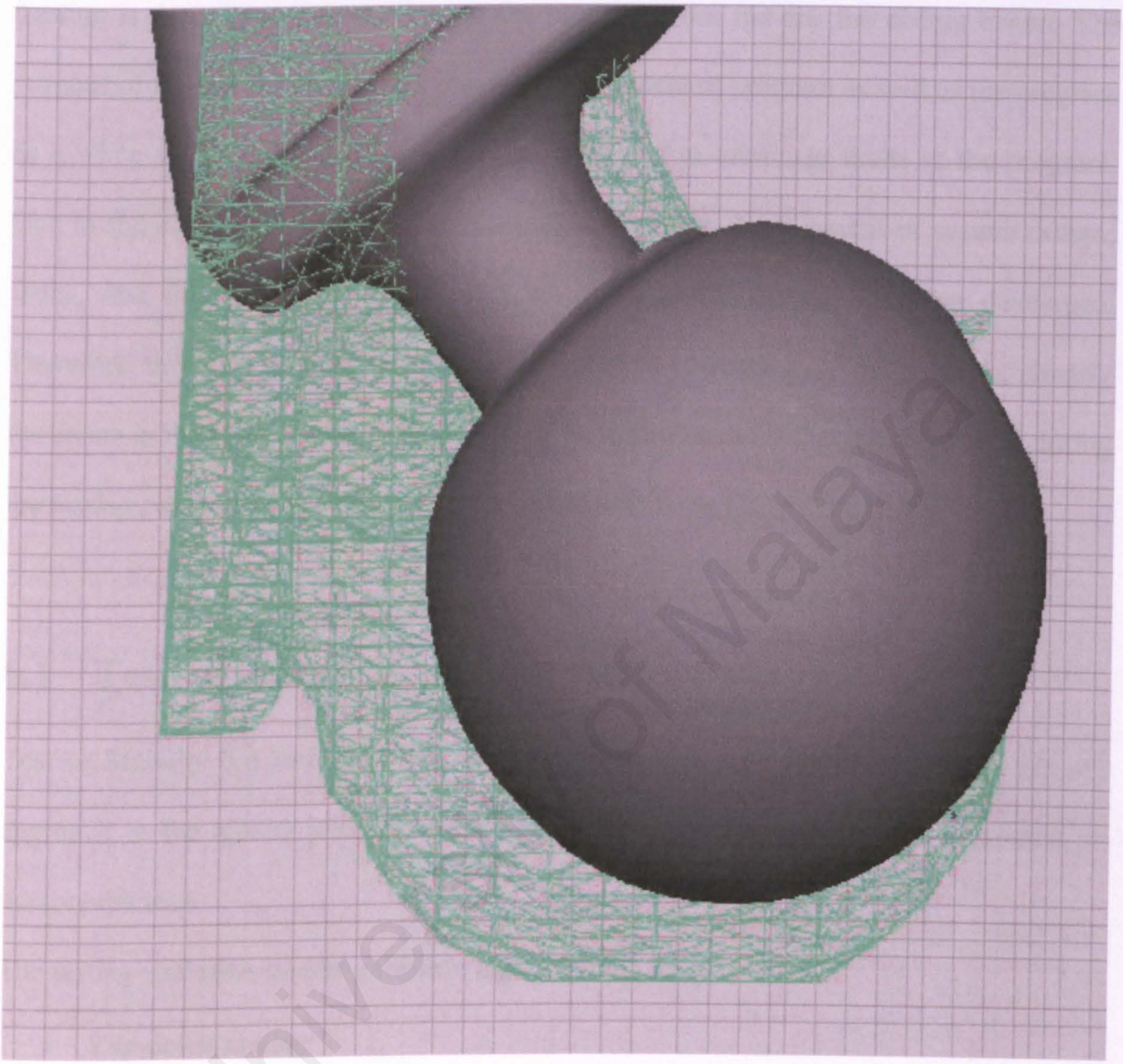


Figure 5.5: After the implant's head scaling

6.0 System Testing

Testing is done from time to time to the program from the day the coding begun. The purpose of testing is to ensure the resulting component of program as well as the program as a while fulfils the requirement specification and to eliminate faults in the program. Due to the errors that has been done during the system development or system design, faults, and failures may happen even when the entire system has been developed. Therefore, the main idea of testing is to demonstrate correctness of the program, identify the errors in the system coding or the system design. The faults that are discovered during the testing procedures must be corrected before launching the system.

6.1 Testing strategy

Testing Strategy is a strategy of establishing the existence of errors. It is also a general approach to the testing process rather than a method of devising particular system or component tests.

The testing strategies consist of following method:

- ***Top-down testing***

  Testing starts with the most abstract component and works downwards until all the modules are tested.

- ***Bottom-up testing***

  It is one of the popular approaches used to test large systems. Testing starts with the fundamental components and works upwards.

- ***Back-to-back testing***

  Used when versions of a system are available. The systems are tested together and their outputs are compared.

- ***Thread testing***

  Used for system with multiple processes where the processing of transition threads its way through these processes.

6.2 System Testing

System testing can be divided into unit testing, integration testing and system testing. Testing is a critical element of software quality assurance and represents the ultimate review of specification, design and coding. A good test case has a high probability of finding an undiscovered error from the system.

The main objectives of system testing are:

- To reveal different classes of errors and do so with a minimum mount of time and effort.
- To ensure the function appear to be working according to the specification.
- To demonstrates that behavioral and performance appear to have been met.

  It is important to let users to test on the system to give a view of the system and any comment from the user is useful to enhance this system based on their requirement. For this system, unit or module testing and top-down testing have been carried out for integration testing.

6.2.1 Unit Testing

Unit testing is to test the program in each module independently. The primary goal of unit or module testing is to confirm that the unit is correctly coded and that it carries function it is suppose to carry out. It is the initial testing stage for the completion of each component class. The interaction testing between components are initially avoided and to carried out later in the bottom-up integration testing.

Unit testing manages the combination of testing, it facilitates errors diagnose and correction by development and it allows parallelism, in other words it test multiple function. All the logical error that contain in the classes will be detected. The following areas were tested during unit testing for this project:

- Boundary values analysis.

Ensure that the module operates properly at boundaries established to limited or restricted processing.

- Handling Paths

Ensure that the specific module executes the recovery process while an error occurs.

- All possible independent program paths are executed.

Ensure that the control structures are implemented correctly.

Examples of test cases

- Ensure that the scaling button will function appropriately and only scale until where we stopped.

- To ensure the module will function as it is specified.

  Unit testing helps to correct the error an all the module. A few errors were identified and corrected after carrying out unit testing.

6.2.2 Integration Testing

Integrated testing is a systematic technique for constructing the program structure while at the same time conducting test to discover the errors. Integration testing is used to ensure that the system will work correctly when all the models and script files combined together. Each model is tested individually first to see the resultant of combining together with the scripts. Then it will be tested to whole system to completing the system. This approach will repeat until all the models being tested.

The goal of carrying out integration testing is to take unit tested components and build a program structure that has been dictating by design. This testing will ensure that each module is arranged and functioning correctly. Below is the testing phrase for the user interface before the final script has been used.

Phrase 1

```
string $window = `window -title "Testing"
      -iconName "Try"
      -widthHeight 100 80`;

   columnLayout -adjustableColumn true;
         string $cuba[]=`sphere`;
         separator -st "double" -w 500 -h 5;
         attrFieldSliderGrp -min -10.0 -max 10.0 -at ($cuba[0]+".tx");
         separator -st "double" -w 500 -h 5;
         attrFieldSliderGrp -min -10.0 -max 10.0 -at ($cuba[0]+".ty");
         separator -st "double" -w 500 -h 10;
         attrFieldSliderGrp -min -10.0 -max 10.0 -at ($cuba[1]+".radius");
         for ($i=0; $i< size($cuba); $i++) print ($cuba[$i] +"\n");
         separator -st "double" -w 500 -h 15;
     button -label "Close" -command ("select -r $cuba[0]; delete ;deleteUI -window " +
$window);

  setParent ..;
  showWindow $window;
```

Phrase 2

```
string $window = `window -title "window1"
      -iconName "Short Name"
      -widthHeight 200 100`;
   columnLayout -adjustableColumn true;
        string $cuba[]=`sphere`;
        separator -st "double" -w 500 -h 5;
        attrFieldSliderGrp -min -10.0 -max 10.0 -at ($cuba[0]+".tx");
        separator -st "double" -w 500 -h 5;
        attrFieldSliderGrp -min -10.0 -max 10.0 -at ($cuba[0]+".ty");
        separator -st "double" -w 500 -h 10;
        attrFieldSliderGrp -min -10.0 -max 10.0 -at ($cuba[1]+".radius");
        for ($i=0; $i< size($cuba); $i++) print ($cuba[$i] +"\n");
        separator -st "double" -w 500 -h 15;
     button -label "test" -command ("test");
        separator -st "double" -w 500 -h 20;
     button -label "Close" -command ("select -r $cuba[0]; delete ;deleteUI -window " +
$window);

  setParent ..;
  showWindow $window;

proc test(){
 string $window = `window`;
  string $form = `formLayout`;
  string $editor = `modelEditor`;
  string $column = `columnLayout -adjustableColumn true`;

  // Create some buttons that will alter the display appearance of
  // objects in the model editor, eg. wireframe vs. shaded mode.
  //
  button -label "Wireframe"
     -command ("modelEditor -edit -displayAppearance wireframe $editor");
  button -label "Points"
     -command ("modelEditor -edit -displayAppearance points $editor");
  button -label "Bounding Box"
     -command ("modelEditor -edit -displayAppearance boundingBox $editor");
  button -label "Smooth Shaded"
     -command ("modelEditor -edit -displayAppearance smoothShaded -dtx on $editor");
  button -label "Flat Shaded"
     -command ("modelEditor -edit -displayAppearance flatShaded $editor");

 // Set up the window layout attachments.
 //
```

```
formLayout -edit
    -attachForm    $column "top"    0
    -attachForm    $column "left"   0
    -attachNone    $column "bottom"
    -attachNone    $column "right"
    -attachForm    $editor "top"    0
    -attachControl $editor "left"   0 $column
    -attachForm    $editor "bottom" 0
    -attachForm    $editor "right"  0
    $form;

  // Create a camera for the editor.  This particular camera will
  // have a close up perspective view of the centre of the ground plane.
  //
  string $camera[] = `camera -centerOfInterest 2.450351
    -position 1.535314 1.135712 1.535314
    -rotation -27.612504 45 0
    -worldUp -0.1290301 0.3488592 -0.1290301`;

  // Attach the camera to the model editor.
  //
  modelEditor -edit -camera $camera[0] $editor;

  showWindow $window;

}
```

6.2.3 Function Testing

Function testing focus on the functionality of the system. It is based on the system functional requirement and it checks that the integration on the system perform it functions as specified on the requirement.

6.2.4 Performance Testing

This testing usually involved the hardware as well as software, when the system performs the function required by the requirements, the testing process then turn to test the way in which those functions are performed. Thus the performance testing addresses the non-functional requirements. The purpose of this testing is to test the run time performance of this software within the context of an integrated system.

6.2.5 Acceptance Testing

This is one of the stages in the testing process before the system is accepted for operational use. The system is tested with data supplied by the system producer rather than simulated test data. Sometimes, this testing is called as alpha testing and this testing process continue until the system developer and client agree that the delivered system is an acceptance implementation of the system requirement.

6.3 Conclusion

Testing is the most important steps in developing the system perfectly. Precision and accuracy of output data or appearance is considered during this process. Unit, integration and system testing has been carried out for this systems. The objective of a system will only achieve after all the through testing done by different user with different aspects.

This chapter describes the types of testing done on the system. There were few types of testing did on the system. All types testing were done to make sure no errors in the complete system before handling it over to the client. The last testing was the acceptance testing tested by the client.

7.0 Systems Evaluation

As this project has to be done within a short span of time and a lot of technical issues need to be resolved, few problems have been encountered solutions have been sought during testing. Encountering with those problems has been proved to be a valuable learning experience.

After finish the project implementation, a report of an evaluation of this project will be discussed in this chapter. I will cover the system strengths and initiations. A few suggestions will made as enhance of the system.

7.1 Problems and Possible Alternatives

Lack of knowledge in programming and less experience in developing system were consuming a lot of times to catch up all this fundamental knowledge. Therefore this project is developed in rushing, and many advance features is not implemented in this project. Doing some time management and listed out all suggested features is helpful during the system development. Only the important part will be implemented in this project.

Among the biggest problem is to simplify the data from point clouds to surfacing modeling software like maya. Data like in point clouds are meant for a solid modeling program (eg, Catia, ProE, GeoMagic), thus the enormous amount of data makes it hard to have a good and responsive operations from programs like Maya. This in turn will slow down the productivity level. Even when the data was exported in the form of OBJ format, even though the amount of data was considerably less then the same file in IGES format, still the file is big for average system usage and responsiveness.

Another problem is of getting the exact point or measurement of the implant, or the measurement entities to do accurate simulations. Procedural approach to the problem could be done provided predefined calculation and measurement entities are available. Among the example is to have basic radius at various points constructed as NURBS curves, then the curves are lofted together to create NURBS surfaces, thus would enable the creation of the implant on the fly within the program.

Another approach that would have been explored provided the above entities are available is to have the implant structure or geometry to be simulated using Maya's built in particle system. Maya particle system is definitely one of the best in the world. Using predefined points on the surface (which could be created procedurally), these particles could be used to detect surface collisions or intersections between the implant and the bone. Together using Maya's built in particle systems, kinematics solutions and joint system, the above simulations could be done in a true procedural style with minimal human intervention.

7.2 System Strength

<u>*Simple User Interface*</u>

All the system requirements are used the simple interfaces to that the users are easy to interact, and handled what they wanted to do with the system. The system includes the simple graphical interfaces to control the object such as scaling factor for the implant's head, rotation factor for the implant's head, scaling factor for the implant's lower and upper body. Users can easily handle and do the simulation activities without long time for training or learning, easily, make them feel so comfortable during using the system.

<u>*Effective Scripting*</u>

MEL (Maya Embedded Language) is a powerful command and scripting language that gives us direct control over Maya's features, processes, and workflow. As we select menu items or otherwise use the interface, Maya performs the operations by internally running MEL commands. In fact, much of Maya's user interface is built using MEL scripts and procedures.

MEL commands can be organized into reusable script files that let us:

- automate tasks might otherwise do more slowly or tediously with the user interface
- use additional Maya features
- create custom user interfaces
- perform specialized workflows
- create new effects

7.3 System Limitations

However, there are limitations in these systems that are not resolved yet.

- System providing no analysis
- Lack Of Detail Structure

  The system could not include a lot of structure due to PC limitation on designing phase. Detail structure in a system mainly could not being build with ordinary PCs like Windows, due to lack of memory usability and performance of the PC's processor.

- Limited Functionality

  This system only provides through offline usage. User can only download and install the program through their PCs.

7.4 Future Enhancement

The system should be maintained throughout the lifetime of the system because the user requirements might vary from times to times. Enhancement in the future will extend the usability of this system. Moreover, the system limitations should be improved to enhance functionality. Here are some suggestion and possible future enhancements:

Enhance User Interface

User interface should enhance from time to time. Multimedia elements such as streaming video entities should be added to increase its attractiveness, impressive and interactive and to make the system multimedia map program.

More Functionality Added

Dynamic key configuration should be added to make sure the system more users friendly and flexible for user to change the configuration like scaling and rotation.

Develop For Other Platform

The system should be design web-base to make sure that user can use the system globally.

7.5 Conclusion and Discussion

This chapter evaluates Interactive Simulation of implant fitting in the hip bone using Maya from different perspectives. It's begins by stating the problems encountered throughout the development and implementation of the system which includes the challenges in learning and development tools. Several problems were encountered during the development phase of this system. However it was solved with the helps of my friends and supervisor and lecturers.

Developing this system has given me the chance to learn Maya 4.5 Unlimited tools. It has also exposed me different minds of latest technology in computer industry. I gained invaluable experiences in managing and developing a project. In accomplishing this project, I become more independent and confidence in handling the software's using the project.

Finally, the real are much more challenges to be research in the field of simulation in medical imaging. This system can be enhanced to a better stand alone or web based system in different kinds of aspects in the future.

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Scripting

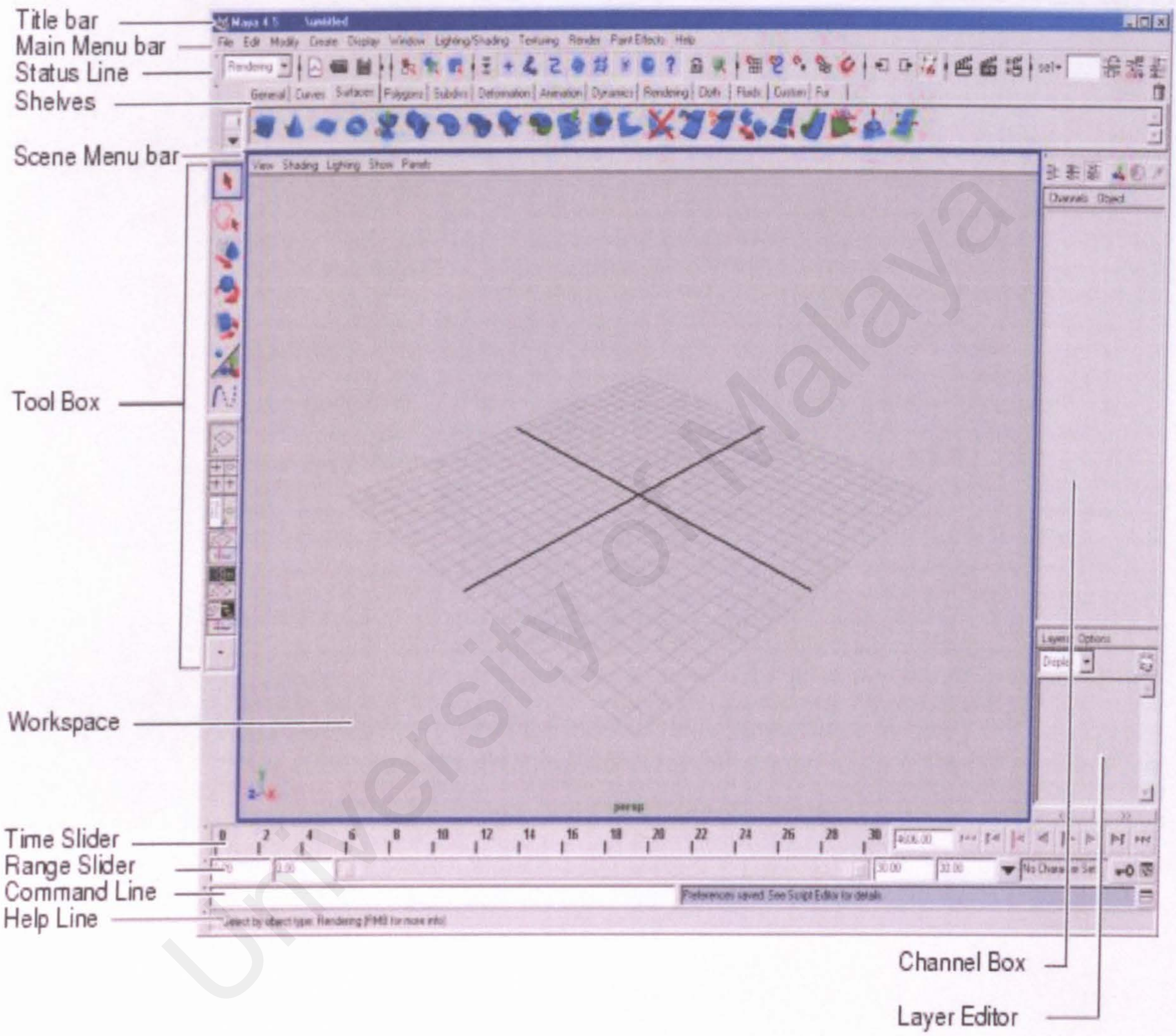
Scripting that has been created for the user interface and for controlling the scaling factor

```
if (`window -exists Bone`) deleteUI Bone;
if (`panel -exists AdvPanelView`) deleteUI -panel AdvPanelView;
window -t "bone Simulation" -wh 450 900 Bone;
paneLayout -cn "horizontal2" -paneSize 1 100 90 TopPanels;

paneLayout -cn "vertical2" SubPanels;
$obj="joint2";
columnLayout;
text "Scaling Factor For The Implant's Head";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sy");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sz");
separator -st "double" -w 500;

$obj="joint1";
columnLayout;
text "Rotation Factor For The Implant's Head";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".rx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".ry");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".rz");
separator -st "double" -w 500;

$obj="joint4";
columnLayout;
text "Scaling Factor For The Implant's Lower Body";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sy");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sz");
separator -st "double" -w 500;

columnLayout;
$obj="joint5";
text "Scaling Factor For The Implant's Upper Body";
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sx");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sy");
attrFieldSliderGrp -min 1.0 -max 10.0 -at ($obj+".sz");
separator -st "double" -w 500;

setParent SubPanels;

modelPanel AdvPanelView;
```

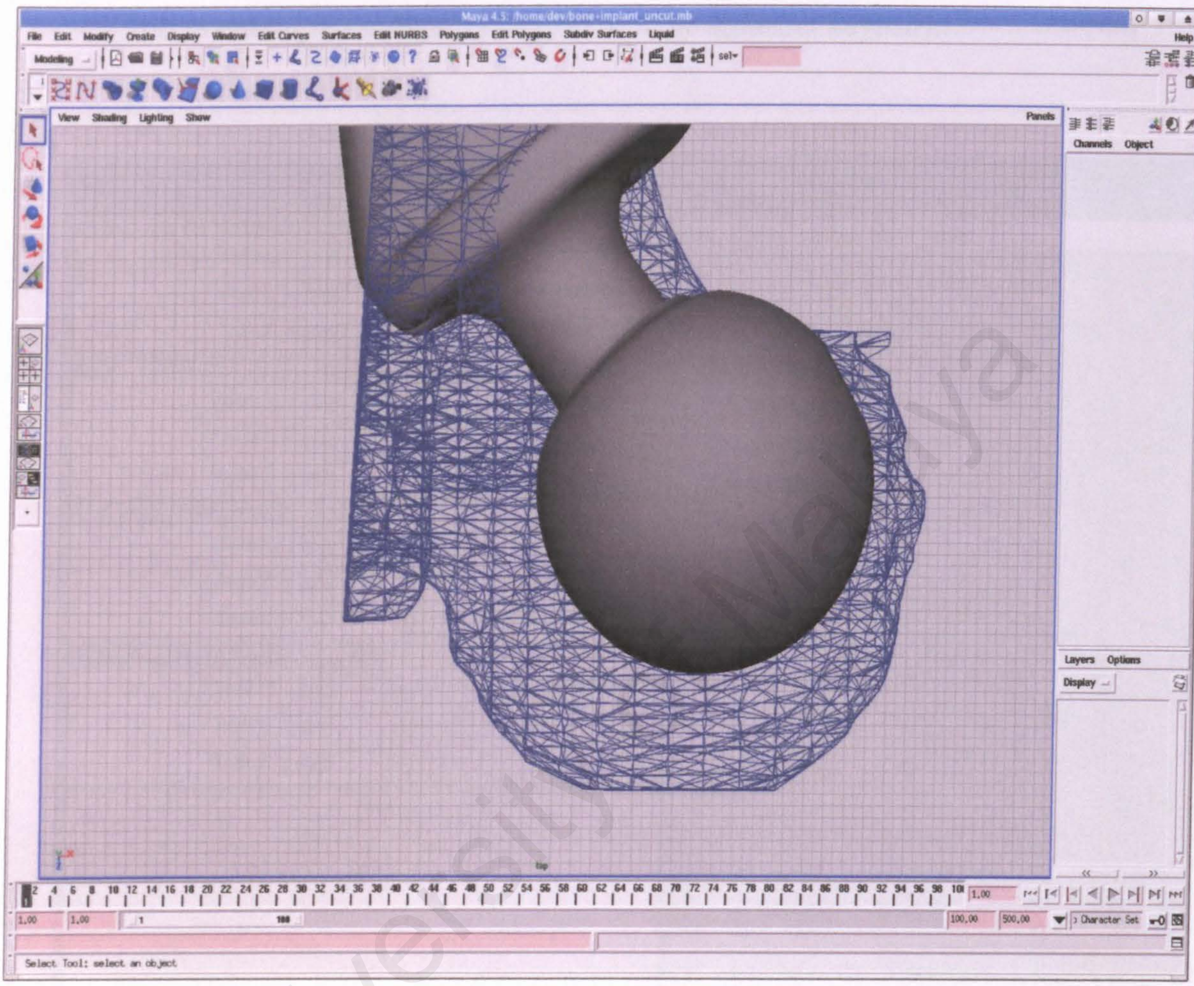
```
modelEditor -edit -displayAppearance smoothShaded AdvPanelView;
setParent SubPanels;
setParent TopPanels;

window -e -wh 800 600 -topLeftCorner 50 50 Bone;
showWindow Bone;
```

User Manual

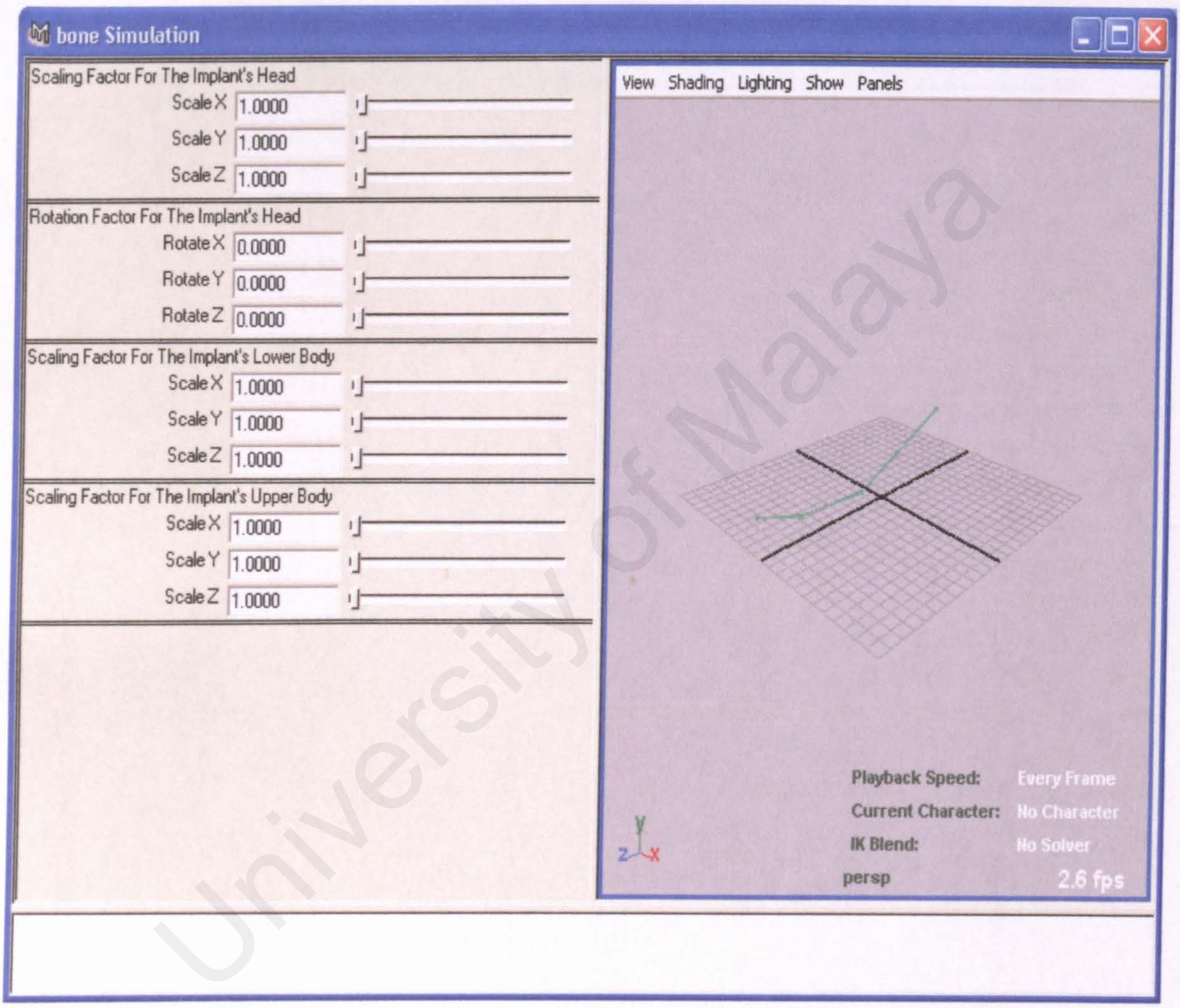
1. Run Maya 4.5 Unlimited by double click at the icon. User interface of Maya is shown as below



2. Go to the file menu and click file>open scene>cd> bone+implant_uncut.mb



3. Copy the script implant-scaling.mel and then open the script editor window>general editor>script editor and paste the script to the script editor and press enter (in numbering keypad, not the alphabet keypad).



4. Finally, u can use the system by clicking the scaling button and do what scaling factor u want to scale.